Extremely wide angle nonreciprocal thermal emitters based on weyl semimetal with dielectric grating structure: a review report of Case Study in Thermal Engineering

By

I NYOMAN SUAMIR, ST, MSc, PhD

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2023

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1. CORRESPONDENCES

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Manuscript Number: CSITE-D-22-00525

Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

Jun Wu; Yasong Sun; Biyuan Wu; Zhongmin Wang; Xiaohu Wu

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Case Studies in Thermal Engineering

Abstract:

Although various nonreciprocal thermal emitters have been suggested to break the balance between absorption and emission, the majority can only achieve nonreciprocal effect at one certain angle, and the angular range in which these structures exhibit nonreciprocal effect is heavily restricted. In this work, the extremely wide-angle nonreciprocal thermal emitters have been proposed and investigated based on magnetic Weyl semimetals. The enhanced and wide-angle nonreciprocal effect is attributed to the excitation of guided mode. The physical origin is revealed by investigating the distribution of electromagnetic field at the resonant wavelength and is also confirmed by the dispersion relation of guided mode. It is believed that this work will provide new approach for the design of novel nonreciprocal thermal emitters.

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Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

Jun Wu; Yasong Sun; Biyuan Wu; Zhongmin Wang; Xiaohu Wu

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I am grateful to you for your assistance as a reviewer for Case Studies in Thermal Engineering.

Kind regards,

Huihe Qiu
Editor-in-Chief
Case Studies in Thermal Engineering

Comments to author:
Reviewer #1: The authors study the non-reciprocal thermal radiation in the form of a dielectric grating separated from the metal mirror by a Weyl semimetal film. It is a topic with timely interest and the authors did thorough calculations showing the effect. My main question, however, lies in the following:
1.The paper should include the latest results in this field. As far as I know, some experiment works concerned with nonreciprocal thermal radiation have been published, the author should discuss it in the introduction.
2.In recently experiment works related with nonreciprocal thermal radiation, the magneto-optical materials, such as InAs, have been investigated. In this work, why the authors used the Weyl semimetal?
3.Does the proposed structure in this work can be fabricated with present technologies?

Reviewer #2: The manuscript presents the extremely wide-angle nonreciprocal thermal emitters investigated based on magnetic Weyl semimetals. The enhanced and wide-angle nonreciprocal effect is attributed to the excitation of guided mode. Minor revision is required in order to improve the quality of content and writing of the manuscript. The content needs additional clarification and revision on points raised which include:
1. The abstract has systematically included a brief background information description, the current gap of research field, method, findings and the contribution to the design of novel nonreciprocal thermal emitters. However, the method or proposed approach and the findings should be more clearly elaborated.
2. The introduction provides clear motivation and objectives of the work. It also explains the current gap of research field. The introduction is also successful to elaborate the exceptionality of the work.
3. The methods applied are briefly described and illustrated. However, the excitation of guided mode as mention in abstract and introduction has not been explained in the methodology section. In addition, this is a numerical investigation, Authors need to explain in the methodology section how: (i) to optimize geometric parameters of the designed emitter; (ii) the numerical results were validated.
4. In results and discussion section, the authors need to add additional paragraphs that illustrate interpretation of the numerical results to the significant of the proposed approach for the design of novel nonreciprocal thermal emitters and for practical applications.
5. Conclusion has highlighted the novelties of the approach.

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Manuscript Number: CSITE-D-22-00525R1
Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

Dear Dr. Suamir,

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Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

Jun Wu; Yasong Sun; Biyuan Wu; Zhongmin Wang; Xiaohu Wu

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Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

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Manuscript Number: CSITE-D-22-00525R2

Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

Jun Wu; Yasong Sun; Biyuan Wu; Zhongmin Wang; Xiaohu Wu

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2. EXAMPLE OF THE ARTICLE TO BE REVIEWED

Case Studies in Thermal Engineering

Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

--Manuscript Draft--

Manuscript Number:	CSITE-D-22-00525
Article Type:	Case study
Keywords:	nonreciprocal thermal emitters; Weyl semimetal; guided mode; wide-angle.
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Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

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Abstract: Although various nonreciprocal thermal emitters have been suggested to break the balance between absorption and emission, the majority can only achieve nonreciprocal effect at one certain angle, and the angular range in which these structures exhibit nonreciprocal effect is heavily restricted. In this work, the extremely wide-angle nonreciprocal thermal emitters have been proposed and investigated based on magnetic Weyl semimetals. The enhanced and wide-angle nonreciprocal effect is attributed to the excitation of guided mode. The physical origin is revealed by investigating the distribution of electromagnetic field at the resonant wavelength and is also confirmed by the dispersion relation of guided mode. It is believed that this work will provide new approach for the design of novel nonreciprocal thermal emitters.

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1. Introduction

Kirchhoff's law is one of the fundamental laws in thermal radiation, which provides the theoretical basis for designing of almost all thermal emitters that we use in engineering [1-6]. In recent years, it has been demonstrated the nonreciprocal materials, whose permittivity tensor is asymmetric, can break the balance between absorption and emission, resulting in violating the traditional Kirchhoff's law [7-11]. The nonreciprocal thermal emitters, which have unequal absorption and emission, have significant promise in solar energy harvesting and radiative cooling [12-14].

Recently, several nonreciprocal thermal emitters have been suggested to break the balance between absorption and emission as strong as possible. Magneto-optical materials are traditional nonreciprocal materials with asymmetric permittivity tensor. However, the intrinsic nonreciprocity of such materials is weak. Therefore, a large magnetic field and sophisticated structures are usually used to enhance the nonreciprocity [15-24]. Zhu et al. designed a magneto-optical material (InAs) grating structure where strong nonreciprocal radiation is achieved at the 15.96 μm wavelength under a 3 T magnetic field [8]. Later, to decrease the operating magnetic field, Zhao et al. proposed a guided mode resonance structure in the form of an InAs film inserted between a dielectric grating and a metallic mirror, which results in the realization of near-complete nonreciprocal radiation under a magnetic field of only 0.3 T [15]. Besides, Wu et al. proposed a structure which consists of a dielectric grating sandwiched between an InAs film and a metallic mirror, where strong nonreciprocal radiation is realized at the wavelength 15.835 μm with a magnetic field of 2 T [16]. Soon afterwards, Wu et al. designed a planar structure based on the coupling effect of a prism to realize strong nonreciprocal radiation [17], however, the prism employed in the scheme limits the integration of the proposed device. Under this circumstance, Wu et al. proposed a magnetophotonic crystal which consists of alternate arranged InAs film and dielectric film, where strong nonreciprocal radiation is realized at angle of 30^o resulting from to the excitation of Tamm plasmon polaritons [18]. However, the strong nonreciprocal radiation mentioned above should be operated with an external magnetic field, which is disadvantage for practical applications.

Magnetic Weyl semimetals, as a newly discovered class of gapless topological matter, have attracted increasing attention recently owe to their intrinsic nonreciprocity without external magnetic field [25-29]. Tsurimaki et al. proposed a scheme which consists of a low-loss dielectric grating on top of a Weyl semimetal to realize nonreciprocal radiation [25]. Later on, Pajovic et al. demonstrated the violation of Kirchhoff's law on a flat Weyl semimetal surface without an external magnetic field or grating structures [26]. However, the nonreciprocity achieved in Ref. [25, 26] is not large enough. Zhao et al. proposed an emitter in the form of Weyl semimetal grating structure atop an optically thick Weyl semimetal substrate which can achieve near-complete violation of Kirchhoff's law [27]. However, the practical fabrication of an optically thick Weyl semimetal is very difficult. To solve these problems, Wu et al. proposed the method of attenuated total reflection to realize perfect nonreciprocal radiation [28].

Although various nonreciprocal thermal emitters can achieve perfect difference between absorption and emission at one certain angle, the angular range in which these structures exhibit nonreciprocal effect is heavily restricted [30].

In this work, the wide-angle nonreciprocal thermal emitters based on Weyl semimetals are proposed and investigated. The numerical results show that the balance between absorption and emission can be broken in an extremely angle range. The enhanced nonreciprocal effect is attributed to the guided mode excited in the Weyl semimetal film, which is confirmed by investigating the electromagnetic field distribution and dispersion relation.

2. Design and methodology

The schematic of the designed thermal emitter is shown in Fig. 1. The emitter is composed of a dielectric grating separated from the metal mirror by a Weyl semimetal film. The emitter is assumed to be supported by a dielectric (fused quartz) substrate. The dielectric grating is made of a periodic array of silicon (Si) strips along the x-axis. The period and the width, as well as the thickness of the Si strip are d, w and h, respectively. The thickness of the Weyl semimetal film is h_w.

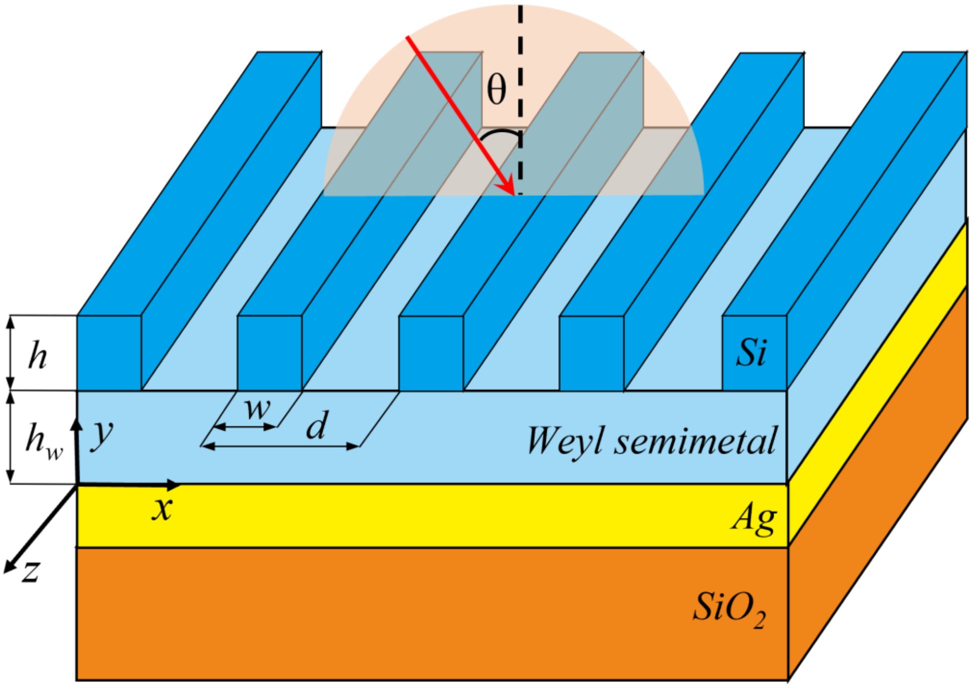

Fig.1 Schematic of the proposed emitter for strong nonreciprocal radiation.

The permittivity of the Si is $\varepsilon_{\mathrm{Si}} = 11.9$. The bottom metallic mirror is made of silver (Ag). Its thickness is set to be 0.2 μm, so there is no transmission. The permittivity of Ag is calculated according to the Drude model as:

$$\varepsilon_{Ag} = \varepsilon_{\infty} - \frac{\omega_p^2}{\omega^2 + j\omega\Gamma} \tag{1}$$

where $\varepsilon_{\infty}=3.4$, $\Gamma=2.7\times10^{13}$ rad/s and $\omega_p=1.39\times10^{16}$ rad/s [31].

In this work, the Weyl nodes of the Weyl semimetal are only considered with the same energy. Besides, we choose the coordinates of the momentum-separation 2b along the *z*-axis direction. Under these conditions, the permittivity tensor the Weyl semimetal can be described by [27]:

$$\varepsilon = \begin{bmatrix} \varepsilon_d & j\varepsilon_a & 0 \\ -j\varepsilon_a & \varepsilon_d & 0 \\ 0 & 0 & \varepsilon_d \end{bmatrix} \tag{2}$$

where

$$\varepsilon_a = \frac{be^2}{2\pi^2\hbar\omega} \tag{3}$$

Since $b\neq0$, ε_a is also nonzero. Therefore, ε becomes asymmetric, which breaks the Lorentz reciprocity of the Maxwell's equation. The detail expression and definition of ε_d can be found in Ref. 27. Here the explicit parameters of the Weyl semimetal are chosen from Ref. 27.

During the simulation, a transverse magnetic (TM) wave is considered and the incident plane is *x*-*y* plane. Incident waves from a channel in the θ direction will be either absorbed by the structure ($\alpha(\theta,\lambda)$), or reflected to the complementary channel in the -θ direction ($R(\theta,\lambda)$). For energy conservation, there is $\alpha(\theta,\lambda)=1-R(\theta,\lambda)$. The emission in the θ direction ($\varepsilon(\theta,\lambda)$) is related to the reflection in the complementary channel by $\varepsilon(\theta,\lambda)=1-R(-\theta,\lambda)$, as can be derived using the thermodynamic argument presented in Refs. [8, 10]. The difference between absorption and emission, i.e., $\eta(\theta,\lambda)=\left|\alpha(-\theta,\lambda)-\varepsilon(-\theta,\lambda)\right|$, is used to measure the nonreciprocal radiation. The reflection can be obtained through the anisotropic rigorous coupled-wave analysis (RCWA) [32-34].

3. Results and discussion

Through optimization efforts, the optimized geometric parameters of the designed emitter are obtained, which are shown as follows: d=5.5 μm, w=3.355 μm, h=0.65 μm, h_w=0.26 μm, θ=30°. In Fig. 2 (a), we show the calculated absorption and emission spectra, as well as the nonreciprocal radiation spectra $\eta=\left|\alpha-e\right|$. As can be seen from Fig. 2, perfect absorption (~98.5%) and emission (~99.8%) are achieved at different wavelength, indicating near-complete violation of the traditional Kirchhoff's law. Besides, the nonreciprocity η is larger than 0.935 at the wavelength of 15.98 μm, which shows a strong nonreciprocal radiation. Fig. 2(b) shows the absorption and emission varying with the angle of incidence at wavelength of 15.98 μm. It can be seen the emission is larger than the absorption at any angles, indicating wide-angle nonreciprocal radiation. As far as we known, such extremely wide-angle nonreciprocal radiation has not been demonstrated in published literature.

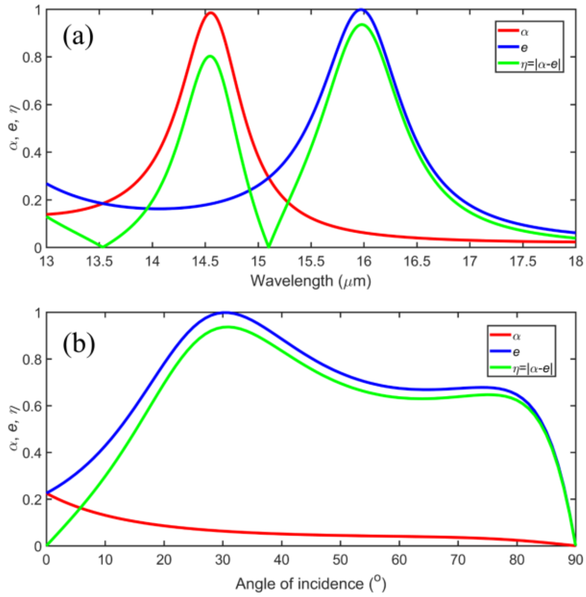

Fig. 2 (a) Absorption (α) and emission (e), as well as the nonreciprocal radiation spectra η at θ=30°. (b) Absorption (α) and emission (e), as well as the nonreciprocal radiation η versus the change of the incident angle at the wavelength of 15.98 μm.

To disclose the physical mechanism of such enhanced nonreciprocity, the magnetic field magnitude distributions at the wavelength of 15.98 μm are simulated for θ=30° and θ=-30°, which are also shown in Figs. 3(a) and 3(b), respectively. Here, the magnetic field magnitude is normalized to the incident magnetic field. As shown in Fig. 3(a), it is found that the magnetic field is strongly enhanced (>15) and concentrated in the Weyl semimetal film, and the distribution shows a stationary wave pattern along the *x*-axis, both of which exhibit a typical feature of guided mode. Therefore, when guided mode is excited, the condition of the critical coupling is achieved, which results in near-complete light absorption and weak reflection in the structure. By comparison, there is much weaker enhancement and concentration of the magnetic field in the Weyl semimetal film for θ=-30°, leading a negligible absorption and strong reflection in the devices, as clearly illustrated in Fig. 3(b).

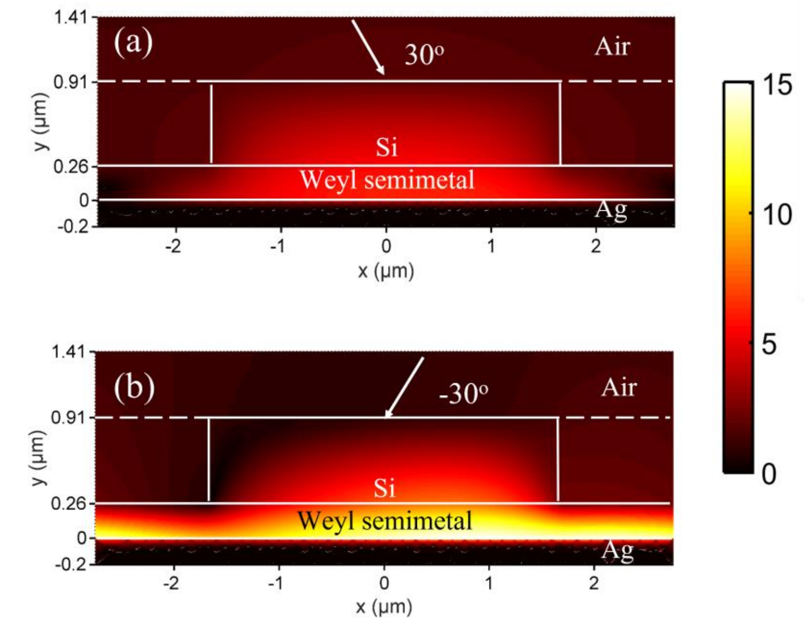

Fig. 3 The distribution of the absolute of the normalized magnetic field H_z at the wavelength of 15.98 μm for (a) θ=30° and (b) θ=-30°.

To confirm that the wide-angle nonreciprocal radiation is attributed to the guided mode, the dispersion of guided mode is investigated. In the appendix, the derivation of the dispersion relation is explicitly presented. The dispersion of the guided mode is

$$\tan\left(k_w h_w\right) = \frac{i\xi_{xx}k_w\kappa\beta\xi_{xy} - i\xi_{xx}k_w\varepsilon_{\mathrm{Si}}\beta\xi_{xy}\kappa + k_d\varepsilon_{\mathrm{Si}}\xi_{xx}k_w}{\xi_{xx}k_w\xi_{xx}k_w\kappa - \beta\xi_{xy}\varepsilon_{\mathrm{Si}}\beta\xi_{xy}\kappa + ik_d\varepsilon_{\mathrm{Si}}\beta\xi_{xy}} \tag{4}$$

where $\kappa = \frac{\gamma_a\varepsilon_{\mathrm{Si}}\sin\left(k_d h_d\right) + k_d\cos\left(k_d h_d\right)}{\gamma_a\varepsilon_{\mathrm{Si}}\cos\left(k_d h_d\right) - k_d\sin\left(k_d h_d\right)}$, $h_d = h*w/d$. The wavevector component along the y-axis in the air, Si grating, and the Weyl semimetal film are $\gamma_a = \sqrt{\beta^2 - k_0^2}$, $k_d = \sqrt{k_0^2\varepsilon_{\mathrm{Si}} - \beta^2}$, $k_w = \sqrt{\left(k_0^2 - \xi_{xx}\beta^2\right)/\xi_{xx}}$, respectively. $\xi_{xx} = \varepsilon_{xx}/\left(\varepsilon_{xx}^2 + \varepsilon_{xy}^2\right)$, $\xi_{xy} = -\varepsilon_{xy}/\left(\varepsilon_{xx}^2 + \varepsilon_{xy}^2\right)$. $\beta = k_0\sin\theta + m\left(2\pi/d\right)$ is the wavevector along the x-axis, where k_0 is the wavevector in the air and m is an integral [33].

The absorption and emission are indirectly calculated by the reflection. The reflection as functions of angle of incidence and wavelength is shown in Fig. 4. As the angle of incidence changes from negative 90° to positive 90°, the weak reflection occurs at smaller wavelength. The reflection is strongly asymmetric about the angle of incidence, resulting in breaking the balance between absorption and emission. It can not only ensure broadband nonreciprocal radiation, but also can ensure wide-angle nonreciprocal radiation. The solid black line is the dispersion of the guided mode, which agrees well with the simulation. Therefore, the dispersion can confirm the excitation of guided mode.

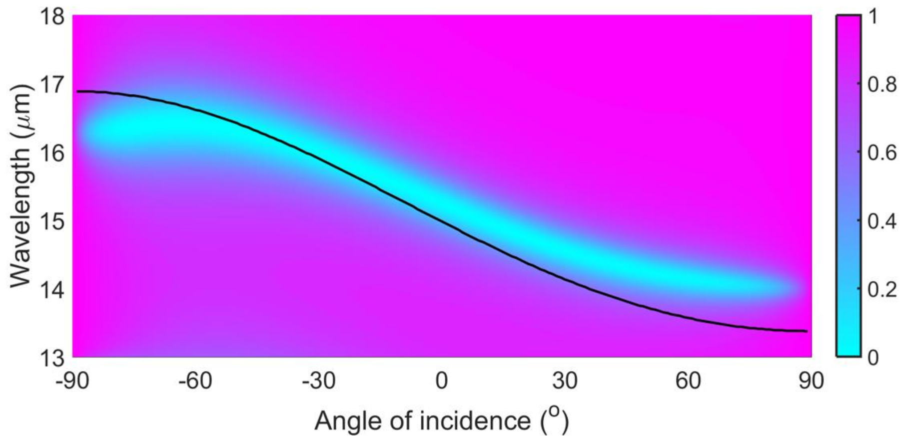

Fig. 4 The reflection as functions of the angle of incidence and the wavelength. The black solid line is the dispersion of the guided modes.

Last, we investigate the effect of the geometric parameters on the nonreciprocal effect. Fig. 5(a) shows the nonreciprocal radiation spectra with the period of the dielectric grating varying from d=5.4 μm to d=5.6 μm. It is seen that the nonreciprocal radiation shifts to shorter wavelength with the increase of d, showing a blueshift. Besides, the difference between the absorption and the emission, i.e., the nonreciprocity η, remains above 0.93. Fig. 5(b) illustrates the nonreciprocal radiation spectra versus the changing of the strip width w. In contrast to the variation of d, the nonreciprocal radiation exhibits a redshift when w increases from 3.3 μm to 3.41 μm. In addition, the nonreciprocity η is still maintained larger than 0.93. Fig. 5(c) shows the nonreciprocal radiation spectra with the grating thickness h increasing from 0.6 μm to 0.7 μm, and this increased h leads to a redshift of the resonance, along with a relatively stable nonreciprocity (η>0.91). Fig. 5(d) shows the nonreciprocal radiation spectra changing with the thickness of the Weyl semimetal film h_w. Clearly, the nonreciprocal radiation spectra show a redshift when h_w changes from 0.24 μm to 0.28 μm, with the corresponding nonreciprocity remaining above 0.92. It is also worth noting that the influence of h_w on the nonreciprocal radiation spectra is larger than those of other structure parameters, which can be employed to tune the nonreciprocal absorption. In general, the strong nonreciprocal absorption performance can be maintained in a large geometric dimension range, which should be interesting for practical fabrication and applications.

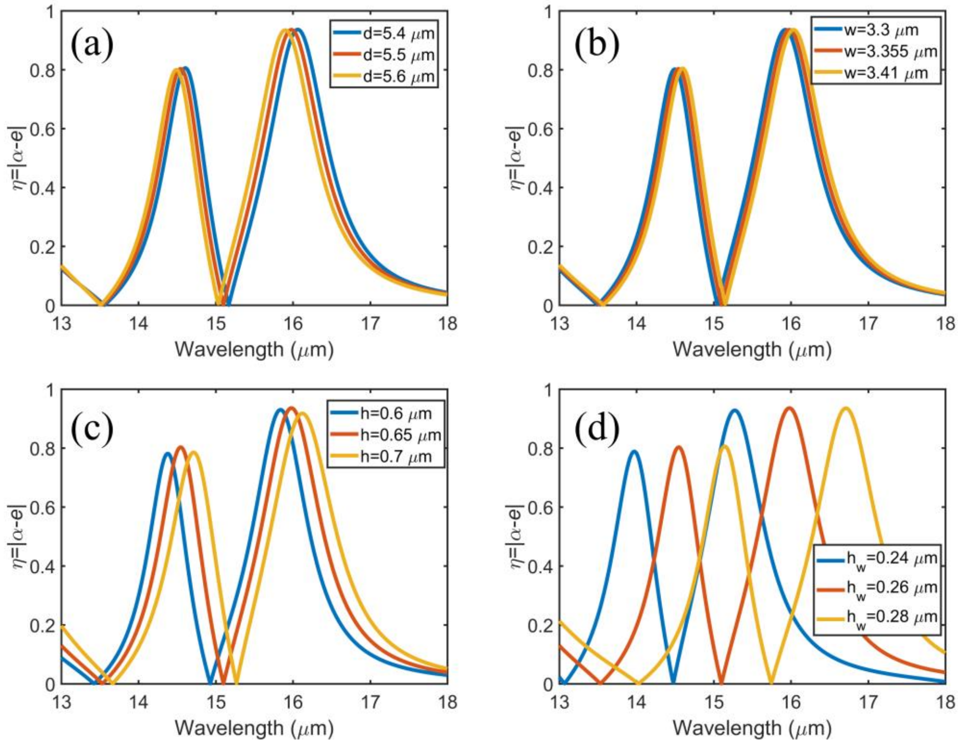

Fig. 5 The nonreciprocal radiation spectra absorption versus the change of the geometric dimensions: (a) the period of the dielectric grating *d*, (b) the width of the dielectric strip *w*, (c) the thickness of the dielectric grating *h*, and (d) the thickness of the Weyl semimetal film h_w. The incident angle is θ=30°.

4. Conclusions

In summary, a novel thermal emitter, in the form of a dielectric grating separated from the metal mirror by a Weyl semimetal film, is designed and investigated. The emitter shows strong nonreciprocal radiation at the wavelength of 15.98 μm when the incident angle is 30°. Such enhanced nonreciprocity is attributed to the excitation of guided mode at the Weyl semimetal film. The distribution of electromagnetic field and dispersion are used to confirm that. Besides, it is found that the emitter possesses wide-angle nonreciprocal radiation properties, in which the angle is wider than any other nonreciprocal emitters demonstrated in published literature. It is hoped that the proposed structure will give insight for designing nonreciprocal thermal emitters.

Appendix: dispersion derivation of guided mode

The nonreciprocal radiation phenomenon can also be quantitatively interpreted by the dispersion relation of the guided mode. For simplicity, the designed structure in Fig. 1(a) can be understood by a multilayer planar structure, which consists of four layers and is shown in Fig 6. Here, the Si grating is simplified as a planar film with the equivalent thickness $h_d=h*w/d$. And the bottom and the upper layers are considered as semi-infinite substrate and superstrate with relative permittivity of $\varepsilon_a=1$ and ε_s, respectively.

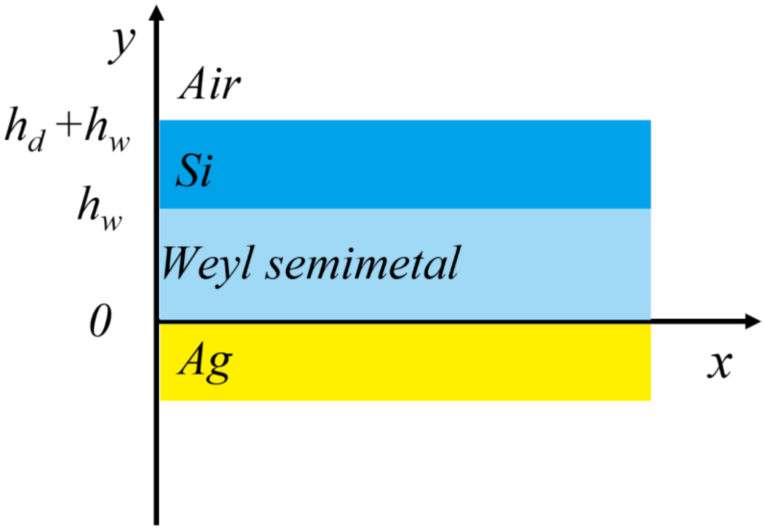

Fig. 6 Schematic of the simplified four layers planar structure.

For convenience and without loss of generality, the permittivity tensor of the Weyl semimetal is redefined as:

$$\varepsilon = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & 0 \\ -\varepsilon_{xy} & \varepsilon_{xx} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{bmatrix} \tag{A1}$$

And the corresponding inverse of the permittivity tensor is defined as:

$$\xi=\begin{bmatrix}\xi_{xx} & \xi_{xy} & 0\\ -\xi_{xy} & \xi_{xx} & 0\\ 0 & 0 & \xi_{zz}\end{bmatrix}=\varepsilon^{-1}=\begin{pmatrix}\varepsilon_{xx} & \varepsilon_{xy} & 0\\ -\varepsilon_{xy} & \varepsilon_{xx} & 0\\ 0 & 0 & \varepsilon_{zz}\end{pmatrix}^{-1}=\begin{bmatrix}\frac{\varepsilon_{xx}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & \frac{-\varepsilon_{xy}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & 0\\ \frac{\varepsilon_{xy}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & \frac{\varepsilon_{xx}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & 0\\ 0 & 0 & \frac{1}{\varepsilon_{zz}}\end{bmatrix} \tag{A2}$$

For TM polarization considered in this work, the electromagnetic components of the guided modes are (H_z, E_x, E_y). The H_z in each region can be expressed as follows:

Layer 1: $y \geq h_w + h_d$

$$H_{z1}=\left(A\cos\left(k_d h_d\right)+B\sin\left(k_d h_d\right)\right)\exp\left(-\gamma_a\left(y-h_w-h_d\right)\right) \tag{A3}$$

Layer 2: $h_w \leq y \leq h_w + h_d$

$$H_{z2}=\left(A\cos\left(k_d\left(\mathrm{y}-h_w\right)\right)+B\sin\left(k_d\left(\mathrm{y}-h_w\right)\right)\right) \tag{A4}$$

Layer 3: $0 \leq y \leq h_w$

$$H_{z3}=\mathrm{C}\cos\left(k_w y\right)+D\sin\left(k_w y\right) \tag{A5}$$

Layer 4: $y \leq 0$

$$H_{z4}=\mathrm{C}\exp\left(\gamma_s y\right) \tag{A6}$$

here β is the propagation constant of the guided modes, $k_d=\sqrt{k_0^2\varepsilon_{\mathrm{Si}}-\beta^2}$, $\gamma_a=\sqrt{\beta^2-k_0^2}$, $\gamma_s=\sqrt{\beta^2-k_0^2\varepsilon_s^2}$, $k_w=\sqrt{\left(k_0^2-\xi_{xx}\beta^2\right)/\xi_{xx}}$, $k_0=2\pi/\lambda$ is the wavevector of the air.

According to the Maxwell's equation, the component E_x at each layer can be expressed as:

Layer 1: $y \geq h_w + h_d$

$$E_{x1}=i\frac{\gamma}{\varepsilon_0\omega}\left(A\cos\left(k_d h_d\right)+B\sin\left(k_d h_d\right)\right)\exp\left(-\gamma_a\left(y-h_w-h_d\right)\right) \tag{A7}$$

Layer 2: $h_w \leq y \leq h_w + h_d$

$$E_{x2} = i\frac{k_d}{\varepsilon_0\omega\varepsilon_{\text{Si}}}\left(A\sin\left(k_d\left(\mathrm{y}-h_w\right)\right)-B\cos\left(k_d\left(\mathrm{y}-h_w\right)\right)\right) \tag{A8}$$

Layer 3: $0 \le y \le h_w$

$$E_{x3} = \frac{1}{\varepsilon_0\omega}\left(\cos\left(k_w y\right)\left(\beta\xi_{xy}C - i\xi_{xx}k_w D\right)+\sin\left(k_w y\right)\left(\beta\xi_{xy}D + i\xi_{xx}k_w C\right)\right) \tag{A9}$$

Layer 4: $y \le 0$

$$E_{x4} = -i\frac{\gamma_s}{\varepsilon_0\omega\varepsilon_s}\mathrm{C}\exp\left(\gamma_s y\right) \tag{A10}$$

Then, based on the boundary conditions of each of E_x and H_z, we can obtain the following equations group:

$$\begin{cases}\left(\gamma_a\varepsilon_{\text{Si}}\cos\left(k_d h_d\right)-k_d\sin\left(k_d h_d\right)\right)A+\left(\gamma_a\varepsilon_{\text{Si}}\sin\left(k_d h_d\right)+k_d\cos\left(k_d h_d\right)\right)B=0\\ A-\mathrm{C}\cos\left(k_w h_w\right)-D\sin\left(k_w h_w\right)=0\\ ik_d B+\varepsilon_{\text{Si}}\left(\cos\left(k_w h_w\right)\beta\xi_{xy}+\sin\left(k_w h_w\right)i\xi_{xx}k_w\right)C+\\ \varepsilon_{\text{Si}}\left(\sin\left(k_w h_w\right)\beta\xi_{xy}-i\xi_{xx}k_w\cos\left(k_w h_w\right)\right)D=0\\ \left(\beta\xi_{xy}\varepsilon_s+i\gamma_s\right)\mathrm{C}-i\xi_{xx}k_w\varepsilon_s D=0\end{cases} \tag{A11}$$

To ensure there is a solution for Eq. (A11), the determinant of the coefficients must be zero, thus, we can obtain the dispersion of the guided mode as:

$$\tan\left(k_w h_w\right)=\frac{\left(i\xi_{xx}k_w\varepsilon_s\kappa\beta\xi_{xy}-i\xi_{xx}k_w\varepsilon_{\text{Si}}\left(\beta\xi_{xy}\varepsilon_s+i\gamma_s\right)\kappa+k_d\varepsilon_{\text{Si}}\xi_{xx}k_w\varepsilon_s\right)}{\left(\xi_{xx}k_w\varepsilon_s\xi_{xx}k_w\kappa-\left(\beta\xi_{xy}\varepsilon_s+i\gamma_s\right)\varepsilon_{\text{Si}}\beta\xi_{xy}\kappa+ik_d\varepsilon_{\text{Si}}\left(\beta\xi_{xy}\varepsilon_s+i\gamma_s\right)\right)} \tag{A12}$$

where

$$\kappa=\frac{\gamma_a\varepsilon_{\text{Si}}\sin\left(k_d h_d\right)+k_d\cos\left(k_d h_d\right)}{\gamma_a\varepsilon_{\text{Si}}\cos\left(k_d h_d\right)-k_d\sin\left(k_d h_d\right)} \tag{A13}$$

For the considered operating wavelengths in this work, the bottom Ag can be assumed as a PEC, thus, $\gamma_s/\varepsilon_s=0$, Eq. (A12) can be simplified to:

$$\tan\left(k_w h_w\right)=\frac{i\xi_{xx}k_w\kappa\beta\xi_{xy}-i\xi_{xx}k_w\varepsilon_{\text{Si}}\beta\xi_{xy}\kappa+k_d\varepsilon_{\text{Si}}\xi_{xx}k_w}{\xi_{xx}k_w\xi_{xx}k_w\kappa-\beta\xi_{xy}\varepsilon_{\text{Si}}\beta\xi_{xy}\kappa+ik_d\varepsilon_{\text{Si}}\beta\xi_{xy}} \tag{A14}$$

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References

1. Z. M. Zhang, Nano/Microscale Heat Transfer (McGraw-Hill, 2007).
2. D. A. B. Miller, L. Zhu, and S. Fan, Universal modal radiation laws for all thermal emitters, Proc. Natl. Acad. Sci. 114, 4336-4341 (2017).
3. W. Li, and S. Fan, Nanophotonic control of thermal radiation for energy applications, Opt. Express 26, 15995-16021 (2018).
4. Y. Li, W. Li, T. Han, X. Zheng, J. Li, B. Li, S. Fan, and C. W. Qiu, Transforming heat transfer with thermal metamaterials and devices, Nature Rev. Mat. 6, 1-20 (2021).
5. D. G. Baranov, Y. Xiao, I. A. Nechepurenko, A. Krasnok, A. Alu, and M. A. Kats, Nanophotonic engineering of far-field thermal emitters, Nature Mat. 18, 920-930 (2019).
6. X. H. Wu, Thermal radiative properties of uniaxial anisotropic materials and their manipulations, Singapore: Springer; 2021.
7. L. Remer, E. Mohler, W. Grill, and B. Luthi, Nonreciprocity in the optical reflection of magnetoplasmas, Phys. Rev. B 30, 3277-3282 (1984).
8. L. Zhu, and S. H. Fan, Near-complete violation of detailed balance in thermal radiation, Phys. Rev. B 90, 220301 (2014).
9. C. Khandekar, F. Khosravi, Z. Li, and Z. Jacob, New spin-resolved thermal radiation laws for nonreciprocal bianisotropic media, New. J. Phys. 22, 123005 (2020).
10. Z. M. Zhang, X. H. Wu, and C. J. Fu, Validity of Kirchhoff's law for semitransparent films made of anisotropic materials, J. Quant. Spectrosc. Ra. 245, 106904 (2020).
11. S. Pajovic, Y. Tsurimaki, X. Qian, and S. V. Boriskina, Radiative heat and

momentum transfer from materials with broken symmetries: opinion, Opt. Mat. Express 11, 3125-3131 (2021).

12. M. A. Green, Time-asymmetric photovoltaics, Nano Lett. 12, 5985-5988 (2012).
13. U. Park, B. Zhao, and S. Fan, Reaching the ultimate efficiency of solar energy harvesting with a nonreciprocal multijunction solar cell, Nano Lett. https://doi.org/10.1021/acs.nanolett.1c04288
14. M. Wei, W. Wu, D. Li, H. Xu, Y. Lu, and W. Song, Universal strategy for all-weather and all-terrain radiative cooling with nonreciprocal mid-infrared windows, Solar Energy 207, 471-478 (2020).
15. B. Zhao, Y. Shi, J. Wang, Z. Zhao, N. Zhao, and S. Fan, Near-complete violation of Kirchhoff's law of thermal radiation with a 0.3 T magnetic field, Opt. Lett. 44, 4203 (2019).
16. X. H. Wu, Z. X. Chen and F. Wu, Strong Nonreciprocal Radiation in a InAs Film by Critical Coupling with a Dielectric Grating, ES Energy Environ. 13, 8-12 (2021).
17. X. H. Wu, The Promising Structure to Verify the Kirchhoff's Law for Nonreciprocal Materials, ES Energy Environ. 12, 46-51 (2021).
18. X. H Wu, R. Y Liu, H. Y Yu and B. Y. Wu, Strong nonreciprocal radiation in magnetophotonic crystals, J. Quant. Spectrosc. Ra., 107794 (2021).
19. M. Liu, C. Zhao, Y. Zeng, Y. Chen, C. Zhao, and C. W. Qiu, Evolution and nonreciprocity of loss-induced topological phase singularity pairs, Phys. Rev. Lett. 127, 266101 (2021).
20. J. Wu, F. Wu, T. Zhao, M. Antezza, and X. H. Wu, Dual-band nonreciprocal thermal radiation by coupling optical Tamm states in magnetophotonic multilayers, Int. J. Thermal Sciences 175, 107457 (2022).
21. J. Wu, and F. Wu, and X. H. Wu, Strong dual-band nonreciprocal radiation based on a four-part periodic metal grating, Opt. Mat. 120, 111476 (2021).
22. M. Q. Liu, and C. Y. Zhao, Near-infrared nonreciprocal thermal emitters induced by asymmetric embedded eigenstates, Int. J. Heat Mass Transfer 186, 122435 (2022).
23. J. Wu, F. Wu, T. Zhao, and X. H. Wu, Tunable nonreciprocal thermal emitter based on metal grating and graphene, Int. J. Thermal Sciences 172, 107316

(2022).

24. J. Wu, F. Wu, T. Zhao, H. Zhai, and X. H. Wu, Nonreciprocal thermal radiation based on Fibonacci quasi-periodic structures, Engineered Science (2022) (DOI: 10.30919/es8d575).
25. Y. Tsurimaki, X. Qian, S. Pajovic, F. Han, M. Li, and G. Chen, Phys. Rev. B 101, 1165426 (2020).
26. S. Pajovic, Y. Tsurimaki, X. Qian, and G. Chen, Large nonreciprocal absorption and emission of radiation in type-I Weyl semimetals with time reversal symmetry breaking, Phys. Rev. B 102, 165417 (2020).
27. B. Zhao, C. Guo, C. A. A. Garcia, P. Narang, and S. H. Fan, Axion-Field-Enabled Nonreciprocal Thermal Radiation in Weyl Semimetals, Nano Lett. 20, 1923-1927, (2020).
28. X. H. Wu, H. Yu, F. Wu, and B. Wu, Enhanced nonreciprocal radiation in Weyl semimetals by attenuated total reflection, AIP Adv. 11, 075106 (2021).
29. J. Wu, Z. Wang, H. Zhai, Z. Shi, X. H. Wu, and F. Wu, Near-complete violation of Kirchhoff’s law of thermal radiation in ultrathin magnetic Weyl semimetal films, Opt. Mat. Express 11, 4058-4066 (2021).
30. B. Zhao, J. Wang, Z. Zhao, C. Guo, Z. Yu, and S. Fan, Nonreciprocal thermal emitters using metasurfaces with multiple diffraction channels, Phys. Rev. Appl. 16, 064001 (2021).
31. X. H. Wu, and C. J. Fu, Unidirectional transmission based on polarization conversion and excitation of magnetic or surface polaritons, AIP Adv. 7, 075208 (2017).
32. X. H. Wu, C. J. Fu, and Z. M. Zhang, Chiral absorbers based on polarization conversion and excitation of magnetic polaritons, ES Energy Environ. 8, 5-14 (2020).
33. M. G. Moharam, E. B. Grann, D. A. Pomment, and T. K. Gaylord, Formulation for stable and efficient implementation of the rigorous coupled-wave analysis of binary gratings, J. Opt. Soc. Am. A 12, 1068-1076 (1995).
34. M. G. Moharam, D. A. Pomment, E. B. Grann, and T. K. Gaylord, Stable implementation of the rigorous coupled-wave analysis for surface-relief gratings: enhanced transmittance matrix approach, J. Opt. Soc. Am. A 12, 1077-1086 (1995).

3. REVIEW COMMENTS

Close

CSITE-D-22-00525
"Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure"
Original Submission

I Nyoman Suamir, PhD (Reviewer 2)

Reviewer Recommendation Term:	Minor Revisions
Overall Reviewer Manuscript Rating:	88

Transfer Authorization	Response
*If this submission is transferred to another journal, do we have consent to share your identity with the receiving journal Editor(s)?	Yes
*If this submission is transferred to another journal, do we have your consent to share your full review with the receiving journal Editor(s)?	Yes

Comments to Editor:

Question 1: The subject addressed in this article is worthy of investigation
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 2: The information presented is new
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 3: The conclusions are supported by the data
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5------------

Question 4: The manuscript is appropriate for the journal
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 5: Organization of the manuscript is appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 6: Figures, tables and supplementary data are appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree

5) Strongly agree
Ans: 4------------

Comments to Author:

The manuscript presents the extremely wide-angle nonreciprocal thermal emitters investigated based on magnetic Weyl semimetals. The enhanced and wide-angle nonreciprocal effect is attributed to the excitation of guided mode. Minor revision is required in order to improve the quality of content and writing of the manuscript. The content needs additional clarification and revision on points raised which include:
1. The abstract has systematically included a brief background information description, the current gap of research field, method, findings and the contribution to the design of novel nonreciprocal thermal emitters. However, the method or proposed approach and the findings should be more clearly elaborated.
2. The introduction provides clear motivation and objectives of the work. It also explains the current gap of research field. The introduction is also successful to elaborate the exceptionality of the work.
3. The methods applied are briefly described and illustrated. However, the excitation of guided mode as mention in abstract and introduction has not been explained in the methodology section. In addition, this is a numerical investigation, Authors need to explain in the methodology section how: (i) to optimize geometric parameters of the designed emitter; (ii) the numerical results were validated.
4. In results and discussion section, the authors need to add additional paragraphs that illustrate interpretation of the numerical results to the significant of the proposed approach for the design of novel nonreciprocal thermal emitters and for practical applications.
5. Conclusion has highlighted the novelties of the approach.

Close

Close

CSITE-D-22-00525R1
"Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure"
Revision 1

I Nyoman Suamir, PhD (Reviewer 2)

Reviewer Recommendation Term:	Minor Revisions
Overall Reviewer Manuscript Rating:	90

Transfer Authorization	Response
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Comments to Editor:

Question 1: The subject addressed in this article is worthy of investigation
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 2: The information presented is new
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 3: The conclusions are supported by the data
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5-----------

Question 4: The manuscript is appropriate for the journal
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 5: Organization of the manuscript is appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 3------------

Question 6: Figures, tables and supplementary data are appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree

5) Strongly agree
Ans: 4------------

Comments to Author:

The authors have revised the paper, but they do not fully response the reviewer comments. The subject addressed in the paper is worthy of investigation. The abstract has systematically included a brief background information description, the current gap of research field, clear method and proposed approach, findings and the contribution to the design of novel nonreciprocal thermal emitters. The introduction provides clear motivation and objectives of the work. It also explains the current gap of research field. The introduction is also successful to elaborate the exceptionality of the work. The authors have also added additional paragraph in Results and discussion section that illustrate interpretation of the numerical results to the significant of the proposed approach for the design of novel nonreciprocal thermal emitters and for practical applications. The conclusion has highlighted the novelties of the approach.

My main doubt is the structure/organization of the paper. The excitation of guided mode as mentioned in abstract and introduction should be explained in the "Design and methodology section" not in the "Results and Discussion section". In addition, the authors need to explain in the design and methodology section how to optimize geometric parameters of the designed emitter and how the numerical results were validated. Please reorganize the paper for proper structure/organization.

The authors also need to clearly explain their responses and what have been done for the revised paper.

Close

Close

CSITE-D-22-00525R2
"Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure"
Revision 2

I Nyoman Suamir, PhD (Reviewer 2)

Reviewer Recommendation Term:	Accept
Overall Reviewer Manuscript Rating:	95

Transfer Authorization	Response
*If this submission is transferred to another journal, do we have consent to share your identity with the receiving journal Editor(s)?	Yes
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Comments to Editor:

Question 1: The subject addressed in this article is worthy of investigation
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5------------

Question 2: The information presented is new
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 4------------

Question 3: The conclusions are supported by the data
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5------------

Question 4: The manuscript is appropriate for the journal
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5------------

Question 5: Organization of the manuscript is appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree
5) Strongly agree
Ans: 5------------

Question 6: Figures, tables and supplementary data are appropriate
1) Strongly disagree
2) Disagree
3) Neutral
4) Agree

5) Strongly agree
Ans: 4------------

Comments to Author:

The authors have comprehensively revised the manuscript. The manuscript is now well structured and organized. The subject addressed in the manuscript is also worthy of investigation. The abstract has systematically included a brief background information description, the current gap of research field, clear method and proposed approach, findings and the contribution to the design of novel nonreciprocal thermal emitters. The introduction provides clear motivation and objectives of the work. It also explains the current gap of research field. The introduction is also successful to elaborate the exceptionality of the work. The authors have also added additional paragraphs that illustrate interpretation of the numerical results to the significant of the proposed approach for the design of novel nonreciprocal thermal emitters and for practical applications. The conclusion has highlighted the novelties of the approach.

I have no objection anymore; the manuscript can be accepted for the journal of Case Studies in Thermal Engineering.

Close

4. PUBLISHED ARTICLE

Case Studies in Thermal Engineering 40 (2022) 102566

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Extremely wide-angle nonreciprocal thermal emitters based on Weyl semimetals with dielectric grating structure

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ARTICLE INFO

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Wide-angle

ABSTRACT

Although various nonreciprocal thermal emitters have been suggested to break the balance between absorption and emission, the majority can only achieve nonreciprocal effect at one certain angle, and the angular range in which these structures exhibit nonreciprocal effect is heavily restricted. In this work, the scheme to realize extremely wide-angle nonreciprocal thermal radiation effect is proposed and investigated. It is achieved by placing a dielectric grating atop a Weyl semimetal film backed with a metal mirror. The results show that the emitter exhibits strong nonreciprocal radiation at the wavelength of 15.98 μm when the incident angle is 30°. What's more, the strong nonreciprocal radiation can be achieved in a wide angular range. Such behavior results from the guided mode resonance, which is revealed by investigating the distribution of electromagnetic field at the resonant wavelength and is also confirmed by the dispersion relation of guided mode. This work provides a new approach to the design of novel nonreciprocal thermal emitters.

1. Introduction

Kirchhoff's law is one of the fundamental laws in thermal radiation, which provides the theoretical basis for designing almost all thermal emitters that we use in engineering [1–6]. In recent years, it has been demonstrated that nonreciprocal materials, whose permittivity tensor is asymmetric, can break the balance between absorption and emission, resulting in violation of the traditional Kirchhoff's law [7–11]. Thus, the nonreciprocal thermal emitters, which have unequal absorption and emission, have significant promise in solar energy harvesting and radiative cooling [12–14].

Recently, several nonreciprocal thermal emitters have been suggested to break the balance between absorption and emission as strong as possible. Magneto-optical materials are traditional nonreciprocal materials with asymmetric permittivity tensor. However, the intrinsic nonreciprocity of such materials is weak. Therefore, a large magnetic field and sophisticated structures are usually used to enhance the nonreciprocity [15–24]. Zhu et al. designed a magneto-optical material (InAs) grating structure where strong nonreciprocal radiation is achieved at the 15.96 μm wavelength under a 3 T magnetic field [8]. Later, to decrease the operating magnetic

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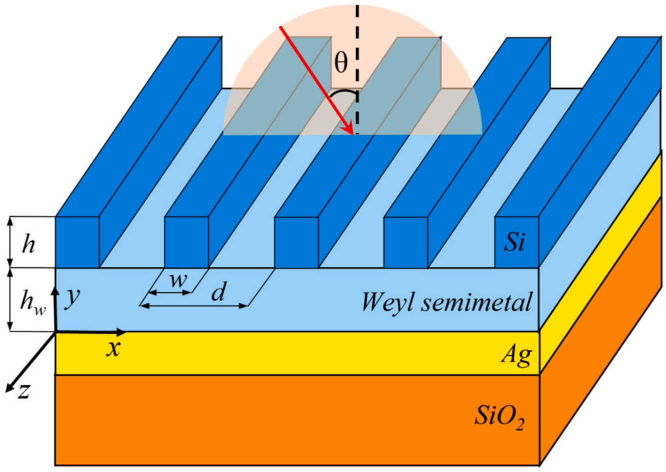

Fig. 1. Schematic of the proposed emitter for strong nonreciprocal radiation.

field, Zhao et al. proposed a guided mode resonance structure in the form of an InAs film inserted between a dielectric grating and a metallic mirror, which results in the realization of near-complete nonreciprocal radiation under a magnetic field of only 0.3 T [15]. Besides, Wu et al. proposed a structure which consists of a dielectric grating sandwiched between an InAs film and a metallic mirror, where strong nonreciprocal radiation is realized at the wavelength 15.835 μm with a magnetic field of 2 T [16]. Soon afterwards, Wu et al. designed a planar structure based on the coupling effect of a prism to realize strong nonreciprocal radiation [17]. However, the prism employed in the scheme limits the integration of the proposed device. Under this circumstance, Wu et al. proposed a magnetophotonic crystal which consists of alternate arranged InAs film and dielectric film, where strong nonreciprocal radiation is realized at angle of 30° resulting from the excitation of Tamm plasmon polaritons [18]. Besides, the nonreciprocal thermal radiation based on InAs has also been experimentally demonstrated very recently [25,26]. However, the strong nonreciprocal radiation mentioned above should be operated with an external magnetic field, which is disadvantage for practical applications.

Magnetic Weyl semimetals, a newly discovered class of gapless topological matter, have recently attracted increasing attention owing to their intrinsic nonreciprocity without external magnetic field [27–31]. Tsurimaki et al. proposed a scheme which consists of a low-loss dielectric grating on top of a Weyl semimetal to realize nonreciprocal radiation [27]. Later on, Pajovic et al. demonstrated the violation of Kirchhoff's law on a flat Weyl semimetal surface without an external magnetic field or grating structures [28]. However, the nonreciprocity achieved in Refs. [27,28] is not large enough. Zhao et al. proposed an emitter in the form of Weyl semimetal grating structure atop an optically thick Weyl semimetal substrate which can achieve near-complete violation of Kirchhoff's law [29]. However, the practical fabrication of an optically thick Weyl semimetal is very difficult. To solve these problems, Wu et al. proposed the method of attenuated total reflection to realize perfect nonreciprocal radiation [30]. Although various nonreciprocal thermal emitters can achieve perfect differences between absorption and emission at one certain angle, the angular range in which these structures exhibit nonreciprocal effect is heavily restricted [32].

In this work, the wide-angle nonreciprocal thermal emitter based on Weyl semimetals is proposed and investigated, which is organized as follows. First, the spectral absorbance and emittance along with the nonreciprocity are simulated to show the strong nonreciprocal radiation at given wavelength and angle. Then the corresponding thermal radiation properties at given wavelength versus the change of incident angle is calculated and analyzed. Next, the physical origin is revealed by investigating the electromagnetic field distribution at resonance and is further confirmed by the dispersion relation of guided mode. Last, the dependence of nonreciprocal radiation effect on the geometric parameters is investigated.

2. Design and methodology

The schematic of the designed thermal emitter is shown in Fig. 1. The emitter is composed of a dielectric grating separated from the metal mirror by a Weyl semimetal film. The emitter is assumed to be supported by a dielectric (fused quartz) substrate. The dielectric grating is made of a periodic array of silicon (Si) strips along the *x*-axis. The period and the width, as well as the thickness of the Si strip are *d*, *w* and *h*, respectively. The thickness of the Weyl semimetal film is h_w.

The permittivity of the Si is $\varepsilon_{Si} = 11.9$. The bottom metallic mirror is made of silver (Ag). Its thickness is set to be 0.2 μm, so there is no transmission. The permittivity of Ag is calculated according to the Drude model as:

$$\varepsilon_{Ag} = \varepsilon_{\infty} - \frac{\omega_p^2}{\omega^2 + j\omega\Gamma} \tag{1}$$

where $\varepsilon_{\infty} = 3.4$, $\Gamma = 2.7 \times 10^{13}$ rad/s and $\omega_p = 1.39 \times 10^{16}$ rad/s [33].

In this work, the Weyl nodes of the Weyl semimetal are only considered with the same energy. Besides, we choose the coordinates of the momentum-separation 2b along the *z*-axis direction. Under these conditions, the permittivity tensor of the Weyl semimetal can be

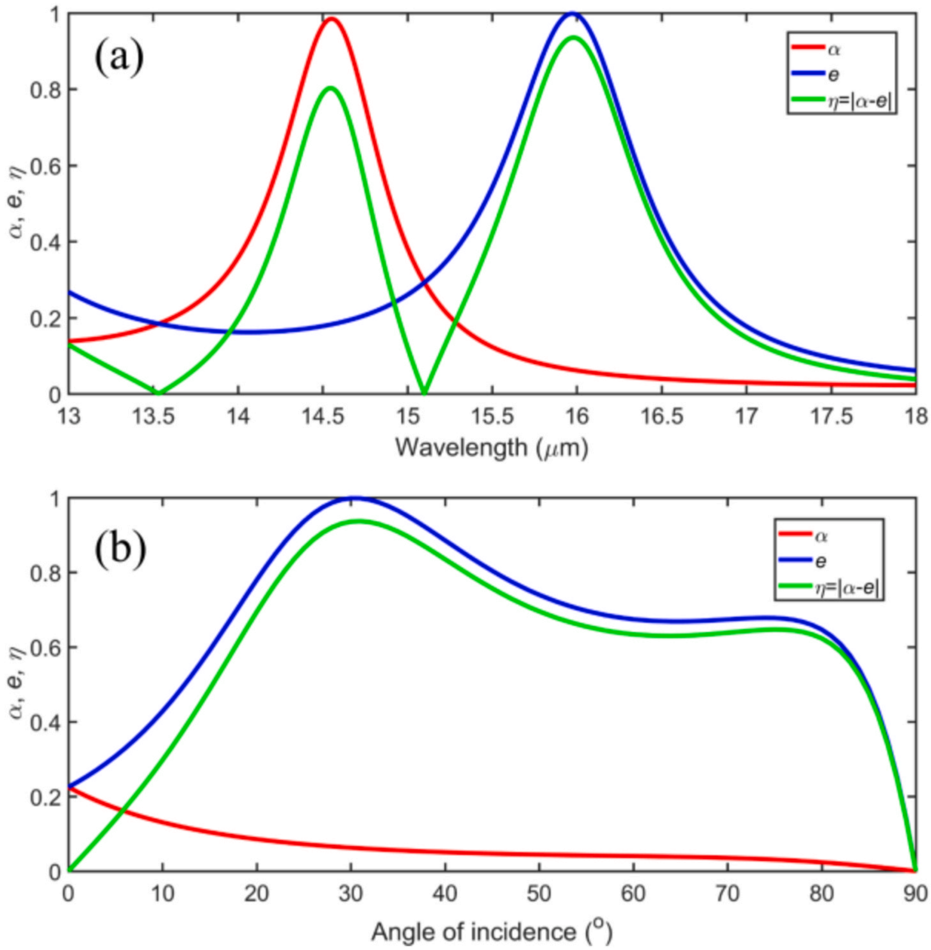

Fig. 2. (a) Absorption (α) and emission (e), as well as the nonreciprocal radiation spectra η at $\theta = 30^\circ$. (b) Absorption (α) and emission (e), as well as the nonreciprocal radiation η versus the change of the incident angle at the wavelength of 15.98 μm.

described by Ref. [29]:

$$\varepsilon = \begin{bmatrix} \varepsilon_d & j\varepsilon_a & 0 \\ -j\varepsilon_a & \varepsilon_d & 0 \\ 0 & 0 & \varepsilon_d \end{bmatrix} \tag{2}$$

where

$$\varepsilon_a = \frac{be^2}{2\pi^2 \hbar\omega} \tag{3}$$

Since $b \neq 0$, ε_a is also nonzero. Therefore, ε becomes asymmetric, which breaks the Lorentz reciprocity of the Maxwell's equation. The detail expression and definition of ε_d can be found in Ref. 29. Here, the explicit parameters of the Weyl semimetal are extracted from Ref. 30.

During the simulation, a transverse magnetic (TM) wave is considered and the incident plane is the *x*-*y* plane. Incident waves from a channel in the θ direction will be either absorbed by the structure ($\alpha(\theta,\lambda)$), or reflected to the complementary channel in the -θ direction ($R(\theta,\lambda)$). For energy conservation, there is $\alpha(\theta,\lambda) = 1 - R(\theta,\lambda)$. The emission in the θ direction ($\varepsilon(\theta,\lambda)$) is related to the reflection in the complementary channel by $\varepsilon(\theta,\lambda) = 1 - R(-\theta,\lambda)$, as can be derived using the thermodynamic argument presented in Refs. [8,10]. The difference between absorption and emission, i.e., $\eta(\theta,\lambda) = |\alpha(\theta,\lambda) - \varepsilon(\theta,\lambda)|$, is used to measure the nonreciprocal radiation. The reflection can be obtained through the anisotropic rigorous coupled-wave analysis (RCWA) [34–36], which is simulated by our home-made code with the number of harmonics being 60. This method has been verified by commercial software and experimental data in our published literatures [37–39].

Here, to obtain the structure dimensions of the proposed emitter, the simulated annealing (SA) algorithm is employed [40,41], and the objective function is:

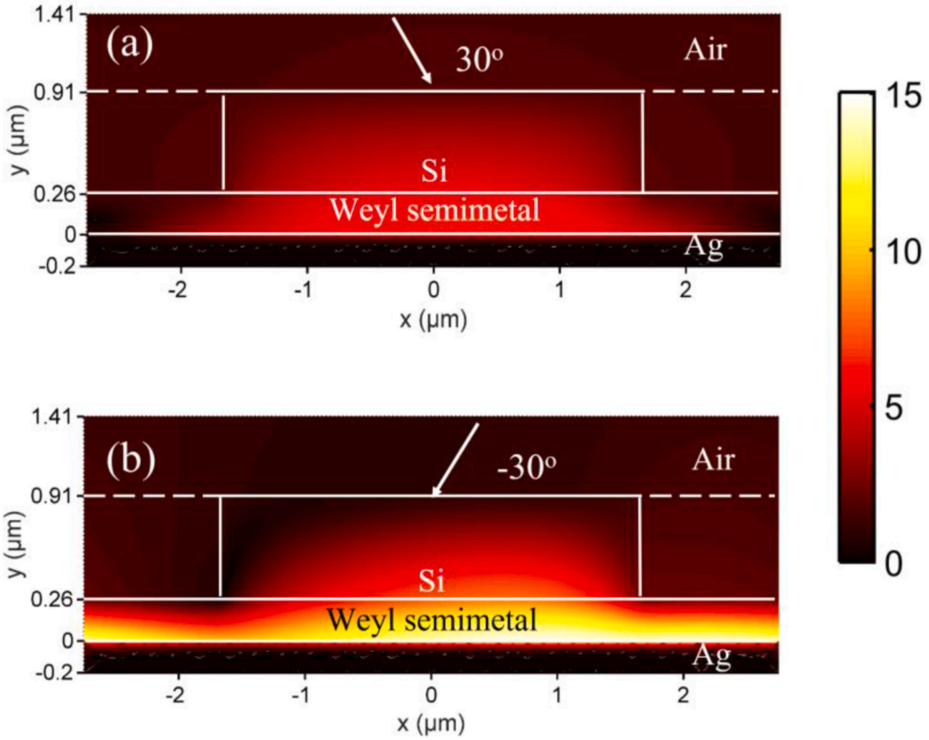

Fig. 3. The distribution of the absolute of the normalized magnetic field H_z at the wavelength of 15.98 μm for (a) θ = 30° and (b) θ = −30°.

$$\varphi(d, w, h, h_w) = -\eta(\theta, \lambda) \tag{4}$$

The optimizing process is based on the built-in SA function of Matlab, where the procedure can be organized: First, a initial estimated parameters is employed to obtaine the initial value of φ (d, w, h, h_w). Then, the structure parameters are changed and a new value of φ (d, w, h, h_w) is recalculated. If the new φ is smaller than the old φ (i.e. the new nonreciprocity is larger), the new structure parameters will be reserved. The process is iterated until the desired nonreciprocity η is achieved.

In addtion, to provide physical understanding of the guided mode excitated in the structure, we derive the dispersion of guided mode, where the explicit derivation procedure is presented in the appendix. The dispersion of the guided mode is

$$\tan(k_w h_w) = \frac{i\xi_{xx}k_w\kappa\beta\xi_{xy} - i\xi_{xx}k_w\varepsilon_{\mathrm{Si}}\beta\xi_{xy}\kappa + k_d\varepsilon_{\mathrm{Si}}\xi_{xx}k_w}{\xi_{xx}k_w\xi_{xx}k_w\kappa - \beta\xi_{xy}\varepsilon_{\mathrm{Si}}\beta\xi_{xy}\kappa + ik_d\varepsilon_{\mathrm{Si}}\beta\xi_{xy}} \tag{5}$$

where $\kappa = \frac{\gamma_a\varepsilon_{\mathrm{Si}}\ \sin(k_d h_d)+k_d\ \cos(k_d h_d)}{\gamma_a\varepsilon_{\mathrm{Si}}\ \cos(k_d h_d)-k_d\ \sin(k_d h_d)}$, $h_d = h^*w/d$. The wavevector component along the y-axis in the air, Si grating, and the Weyl semimetal film are $\gamma_a = \sqrt{\beta^2 - k_0^2}$, $k_d = \sqrt{k_0^2\varepsilon_{\mathrm{Si}} - \beta^2}$, $k_w = \sqrt{(k_0^2 - \xi_{xx}\beta^2)/\xi_{xx}}$, respectively. $\xi_{xx} = \varepsilon_{xx}/(\varepsilon_{xx}^2 + \varepsilon_{xy}^2)$, $\xi_{xy} = -\varepsilon_{xy}/(\varepsilon_{xx}^2 + \varepsilon_{xy}^2)$. $\beta = k_0 \sin\theta + m(2\pi/d)$ is the wavevector along the x-axis, where k_0 is the wavevector in the air and m is an integral.

3. Results and discussion

Through optimization efforts, the optimized geometric parameters of the designed emitter are obtained, which are shown as follows: $d = 5.5$ μm, $w = 3.355$ μm, $h = 0.65$ μm, $h_w = 0.26$ μm, $\theta = 30°$. In Fig. 2 (a), we show the calculated absorption and emission spectra, as well as the nonreciprocal radiation spectra $\eta = |\alpha - e|$. As can be seen from Fig. 2(a), perfect absorption (~98.5%) and emission (~99.8%) are achieved at different wavelengths, indicating near-complete violation of the traditional Kirchhoff's law. Besides, the nonreciprocity η is larger than 0.935 at the wavelength of 15.98 μm, which shows strong nonreciprocal radiation. Fig. 2(b) shows the absorption and emission varying with the angle of incidence at wavelength of 15.98 μm. It can be seen the emission is larger than the absorption at any angle, indicating wide-angle nonreciprocal radiation. As far as we know, such extremely wide-angle nonreciprocal radiation has not been demonstrated in published literature. In practice, separately controlling the absorption and emission of one structure in a wide angular range is very important. For example, to improve the performance of solar thermophotovoltaics, it is necessary to possess high absorption and low emission in a wide angular range. This design is robust to the change of incident angle, which can reduce thermal radiation loss and significantly improve solar energy harvesting efficiency. Thus, the proposed structure suggests promising broad applicability in solar thermophotovoltaics.

To disclose the physical mechanism of such enhanced nonreciprocity, the magnetic field magnitude distributions at the wavelength

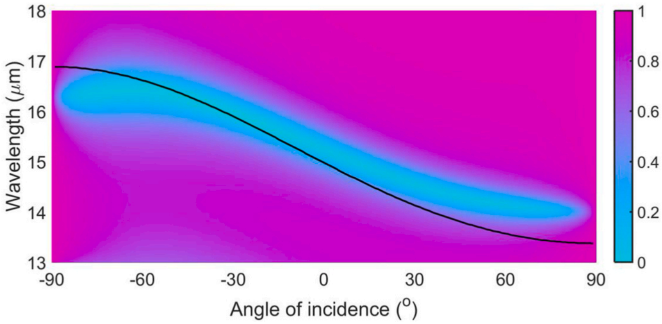

Fig. 4. The reflection as functions of the angle of incidence and the wavelength. The black solid line is the dispersion of the guided modes.

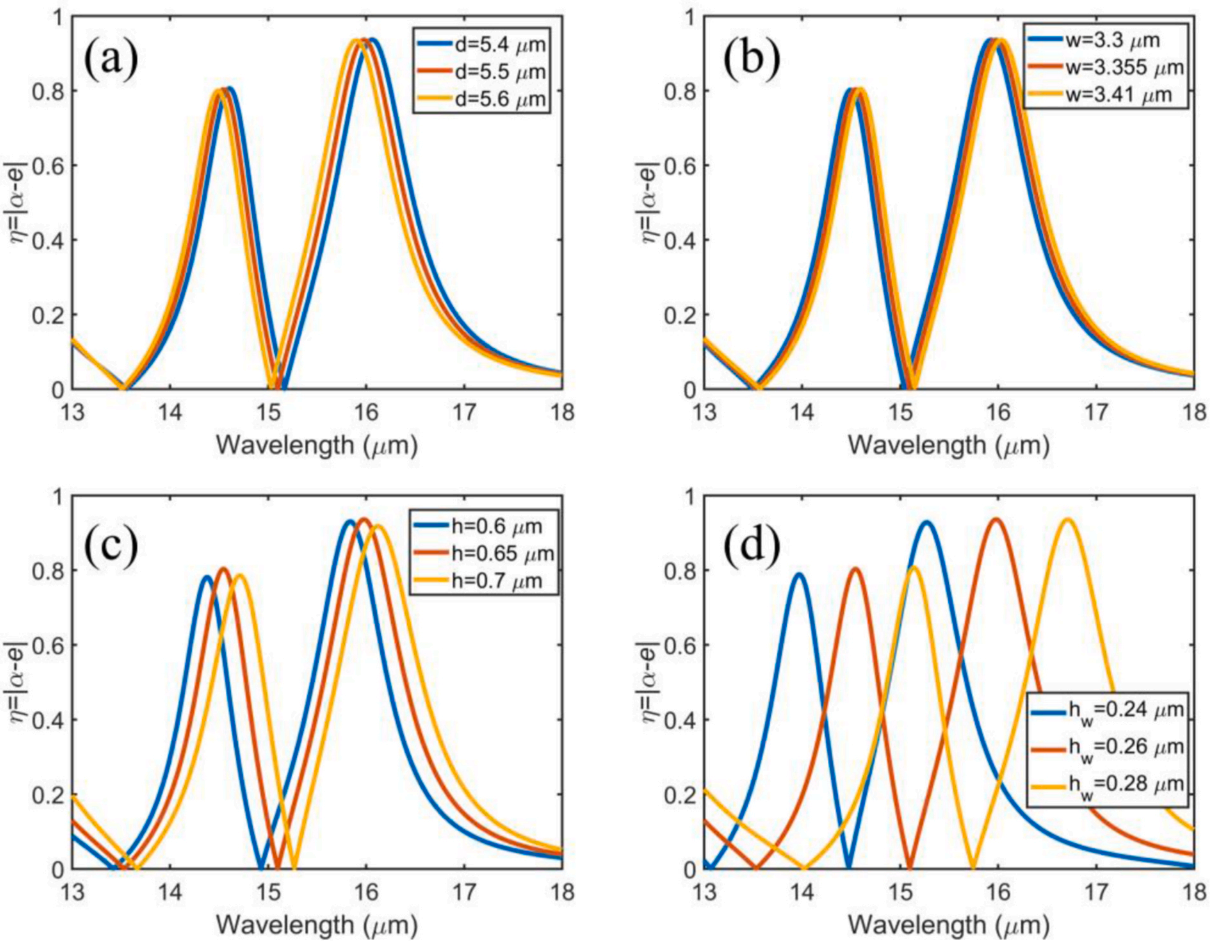

Fig. 5. The nonreciprocal radiation spectra absorption versus the change of the geometric dimensions: (a) the period of the dielectric grating d, (b) the width of the dielectric strip w, (c) the thickness of the dielectric grating h, and (d) the thickness of the Weyl semimetal film h_w. The incident angle is $\theta = 30^\circ$.

of 15.98 μm are simulated for $\theta = 30^\circ$ and $\theta = -30^\circ$, which are also shown in Fig. 3(a) and (b), respectively. Here, the magnetic field magnitude is normalized to the incident magnetic field. As shown in Fig. 3(a), it is found that the magnetic field is strongly enhanced (>15) and concentrated in the Weyl semimetal film, and the distribution shows a stationary wave pattern along the *x*-axis, both of which exhibit a typical feature of guided mode. Therefore, when guided mode is excited, the condition of the critical coupling is achieved, which results in near-complete light absorption and weak reflection in the structure. By comparison, there is much weaker enhancement and concentration of the magnetic field in the Weyl semimetal film for $\theta = -30^\circ$, leading to negligible absorption and strong reflection in the devices, as clearly illustrated in Fig. 3(b).

Furthermore, to confirm that the wide-angle nonreciprocal radiation is attributed to the guided mode, we shown the simulated

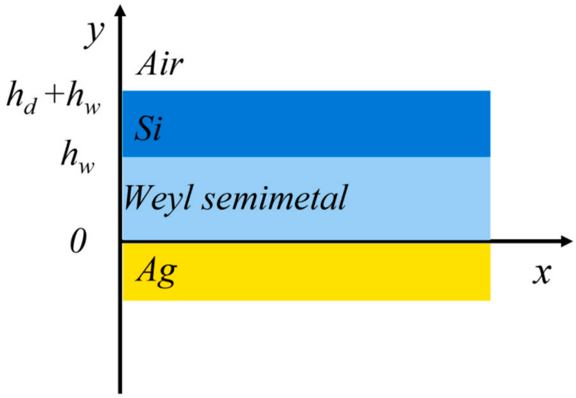

Fig. 6. Schematic of the simplified four layers planar structure.

reflection as functions of angle of incidence and wavelength (since the absorption and emission can be indirectly obtained by the reflection) as well as the dispersion of the guided mode in Fig. 4. As the angle of incidence changes from negative 90° to positive 90°, the weak reflection occurs at a smaller wavelength. The reflection is strongly asymmetric about the angle of incidence, resulting in breaking the balance between absorption and emission. It can not only ensure broadband nonreciprocal radiation, but also can ensure wide-angle nonreciprocal radiation. The solid black line is the dispersion of the guided mode, which agrees well with the simulation. Therefore, the dispersion can confirm the excitation of guided mode.

Last, we investigate the effect of the geometric parameters on the nonreciprocal effect. Fig. 5(a) shows the nonreciprocal radiation spectra with the period of the dielectric grating varying from $d = 5.4$ μm to $d = 5.6$ μm. It is seen that the nonreciprocal radiation shifts to a shorter wavelength with the increase of d, showing a blueshift. Besides, the difference between the absorption and the emission, i.e., the nonreciprocity η, remains above 0.93. Fig. 5(b) illustrates the nonreciprocal radiation spectra versus the changing of the strip width w. In contrast to the variation of d, the nonreciprocal radiation exhibits a redshift when w increases from 3.3 μm to 3.41 μm. In addition, the nonreciprocity η is still maintained larger than 0.93. Fig. 5(c) shows the nonreciprocal radiation spectra with the grating thickness h increasing from 0.6 μm to 0.7 μm, and this increased h leads to a redshift of the resonance, along with a relatively stable nonreciprocity ($\eta > 0.91$). Fig. 5(d) shows the nonreciprocal radiation spectra changing with the thickness of the Weyl semimetal film h_w. Clearly, the nonreciprocal radiation spectra show a redshift when h_w changes from 0.24 μm to 0.28 μm, with the corresponding nonreciprocity remaining above 0.92. It is also worth noting that the influence of h_w on the nonreciprocal radiation spectra is larger than those of other structure parameters, which can be employed to tune the nonreciprocal absorption. In general, the strong nonreciprocal absorption performance can be maintained in a large geometric dimension range, which should be interesting for practical fabrication and applications.

Here, though only numerical simulation has been investigated, for practical manufacture, the device can be fabricated as follows: first, the Ag film is coated on the SiO2 substrate. Then, the Weyl semimetal planar is achieved by exfoliating from the chemical vapor deposition (CVD)-grown single crystal, which can be deposited atop Ag film. Last, the top Si grating can be fabricated by traditional lithography.

4. Conclusions

In summary, we designed and investigated a novel thermal emitter in the form of a dielectric grating separated from the metal mirror by a Weyl semimetal film. The emitter shows strong nonreciprocal radiation at the wavelength of 15.98 μm when the incident angle is 30°. Such enhanced nonreciprocity is attributed to the excitation of guided mode at the Weyl semimetal film, which is revealed by the electromagnetic field distribution and confirmed by the dispersion of guided mode. Besides, it is found that the emitter possesses wide-angle nonreciprocal radiation properties, in which the angle is wider than any other nonreciprocal emitters demonstrated in published literature. Furthermore, the strong nonreciprocal absorption performance can also be maintained in a large geometric dimension range, which should be attractive for practical fabrication and applications. It is hoped that the proposed structure will give insight for designing novel nonreciprocal thermal emitters.

Author statement

Jun Wu: Formal analysis, Writing - original draft, Conceptualization, Writing - review & editing, Funding acquisition. **Yasong Sun**: Data curation, Writing - review & editing. **Biyuan Wu:** Methodology, Writing - review & editing, Formal analysis. **Zhongmin Wang:** Conceptualization, Writing - review & editing. **Xiaohu Wu**: Supervision, Formal analysis, Conceptualization, Writing - review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix. dispersion derivation of guided mode

The nonreciprocal radiation phenomenon can also be quantitatively interpreted by the dispersion relation of the guided mode. For simplicity, the designed structure in Fig. 1(a) can be understood as a multilayer planar structure, which consists of four layers and is shown in Fig. 6. Here, the Si grating is simplified as a planar film with the equivalent thickness $h_d = h^*w/d$. The bottom and the upper layers are considered as semi-infinite substrates and superstates with relative permittivity of $\varepsilon_a = 1$ and ε_s, respectively.

For convenience and without loss of generality, the permittivity tensor of the Weyl semimetal is redefined as:

$$\varepsilon = \begin{bmatrix} \varepsilon_{xx} & \varepsilon_{xy} & 0 \\ -\varepsilon_{xy} & \varepsilon_{xx} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{bmatrix} \tag{A1}$$

The corresponding inverse of the permittivity tensor is defined as:

$$\xi = \begin{bmatrix} \xi_{xx} & \xi_{xy} & 0 \\ -\xi_{xy} & \xi_{xx} & 0 \\ 0 & 0 & \xi_{zz} \end{bmatrix} = \varepsilon^{-1} = \begin{pmatrix} \varepsilon_{xx} & \varepsilon_{xy} & 0 \\ -\varepsilon_{xy} & \varepsilon_{xx} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{pmatrix}^{-1} = \begin{bmatrix} \frac{\varepsilon_{xx}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & \frac{-\varepsilon_{xy}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & 0 \\ \frac{\varepsilon_{xy}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & \frac{\varepsilon_{xx}}{\varepsilon_{xx}^2+\varepsilon_{xy}^2} & 0 \\ 0 & 0 & \frac{1}{\varepsilon_{zz}} \end{bmatrix} \tag{A2}$$

For TM polarization considered in this work, the electromagnetic components of the guided modes are (H_z, E_x, E_y). The H_z in each region can be expressed as follows:

Layer 1: $y \geq h_w + h_d$ $y \geq h_w + h_d$

$$H_{z1} = (A\cos(k_d h_d) + B\sin(k_d h_d))\exp(-\gamma_a(y - h_w - h_d)) \tag{A3}$$

Layer 2: $h_w \leq y \leq h_w + h_d$

$$H_{z2} = (A\cos(k_d(y - h_w)) + B\sin(k_d(y - h_w))) \tag{A4}$$

Layer 3: $0 \leq y \leq h_w$

$$H_{z3} = C\cos(k_w y) + D\sin(k_w y) \tag{A5}$$

Layer 4: $y \leq 0$

$$H_{z4} = C\exp(\gamma_s y) \tag{A6}$$

Here, β is the propagation constant of the guided modes, $k_d = \sqrt{k_0^2\varepsilon_{Si} - \beta^2}$, $\gamma_a = \sqrt{\beta^2 - k_0^2}$, $\gamma_s = \sqrt{\beta^2 - k_0^2\varepsilon_s^2}$, $k_w = \sqrt{(k_0^2 - \xi_{xx}\beta^2)/\xi_{xx}}$, $k_0 = 2\pi/\lambda$ is the wavevector of the air.

According to Maxwell's equation, the component E_x at each layer can be expressed as:

Layer 1: $y \geq h_w + h_d$ $y \geq h_w + h_d$

$$E_{x1} = i\frac{\gamma}{\varepsilon_0\omega}(A\cos(k_d h_d) + B\sin(k_d h_d))\exp(-\gamma_a(y - h_w - h_d)) \tag{A7}$$

Layer 2: $h_w \leq y \leq h_w + h_d$

$$E_{x2} = i\frac{k_d}{\varepsilon_0\omega\varepsilon_{Si}}(A\sin(k_d(y - h_w)) - B\cos(k_d(y - h_w))) \tag{A8}$$

Layer 3: $0 \leq y \leq h_w$

$$E_{x3} = \frac{1}{\varepsilon_0\omega}\left(\cos(k_w y)\left(\beta\xi_{xy}C - i\xi_{xx}k_w D\right) + \sin(k_w y)\left(\beta\xi_{xy}D + i\xi_{xx}k_w C\right)\right) \tag{A9}$$

Layer 4: $y \leq 0$

$$E_{x4} = -i\frac{\gamma_s}{\varepsilon_0 \omega \varepsilon_s} C\exp(\gamma_s y) \tag{A10}$$

Then, based on the boundary conditions of each of E_x and H_z, we can obtain the following equations group:

$$\begin{cases} (\gamma_a \varepsilon_{\text{Si}} \cos(k_d h_d) - k_d \sin(k_d h_d))A + (\gamma_a \varepsilon_{\text{Si}} \sin(k_d h_d) + k_d \cos(k_d h_d))B = 0 \\ A - C\cos(k_w h_w) - D\sin(k_w h_w) = 0 \\ ik_d B + \varepsilon_{\text{Si}}\left(\cos(k_w h_w)\beta\xi_{xy} + \sin(k_w h_w) i\xi_{xx} k_w\right)C + \\ \varepsilon_{\text{Si}}\left(\sin(k_w h_w)\beta\xi_{xy} - i\xi_{xx} k_w \cos(k_w h_w)\right)D = 0 \\ \left(\beta\xi_{xy}\varepsilon_s + i\gamma_s\right)C - i\xi_{xx} k_w \varepsilon_s D = 0 \end{cases} \tag{A11}$$

To ensure there is a solution for Eq. (A11), the determinant of the coefficients must be zero, thus, we can obtain the dispersion of the guided mode as:

$$\tan(k_w h_w) = \frac{\left(i\xi_{xx} k_w \varepsilon_s \kappa \beta \xi_{xy} - i\xi_{xx} k_w \varepsilon_{\text{Si}}\left(\beta\xi_{xy}\varepsilon_s + i\gamma_s\right)\kappa + k_d \varepsilon_{\text{Si}} \xi_{xx} k_w \varepsilon_s\right)}{\left(\xi_{xx} k_w \varepsilon_s \xi_{xx} k_w \kappa - \left(\beta\xi_{xy}\varepsilon_s + i\gamma_s\right)\varepsilon_{\text{Si}} \beta\xi_{xy}\kappa + ik_d \varepsilon_{\text{Si}}\left(\beta\xi_{xy}\varepsilon_s + i\gamma_s\right)\right)} \tag{A12}$$

where

$$\kappa = \frac{\gamma_a \varepsilon_{\text{Si}} \sin(k_d h_d) + k_d \cos(k_d h_d)}{\gamma_a \varepsilon_{\text{Si}} \cos(k_d h_d) - k_d \sin(k_d h_d)} \tag{A13}$$

For the considered operating wavelengths in this work, the bottom Ag can be assumed as a PEC, thus, $\gamma_s/\varepsilon_s = 0$, Eq. (A12) can be simplified to:

$$\tan(k_w h_w) = \frac{i\xi_{xx} k_w \kappa \beta \xi_{xy} - i\xi_{xx} k_w \varepsilon_{\text{Si}} \beta \xi_{xy} \kappa + k_d \varepsilon_{\text{Si}} \xi_{xx} k_w}{\xi_{xx} k_w \xi_{xx} k_w \kappa - \beta\xi_{xy} \varepsilon_{\text{Si}} \beta \xi_{xy} \kappa + ik_d \varepsilon_{\text{Si}} \beta \xi_{xy}} \tag{A14}$$

References

[1] Z.M. Zhang, Nano/Microscale Heat Transfer, McGraw-Hill, 2007.
[2] D.A.B. Miller, L. Zhu, S. Fan, Universal modal radiation laws for all thermal emitters, Proc. Natl. Acad. Sci. USA 114 (2017) 4336–4341.
[3] W. Li, S. Fan, Nanophotonic control of thermal radiation for energy applications, Opt Express 26 (2018) 15995–16021.
[4] Y. Li, W. Li, T. Han, X. Zheng, J. Li, B. Li, S. Fan, C.W. Qiu, Transforming heat transfer with thermal metamaterials and devices, Nat. Rev. Mater. 6 (2021) 1–20.
[5] D.G. Baranov, Y. Xiao, I.A. Nechepurenko, A. Krasnok, A. Alu, M.A. Kats, Nanophotonic engineering of far-field thermal emitters, Nat. Mater. 18 (2019) 920–930.
[6] X.H. Wu, Thermal Radiative Properties of Uniaxial Anisotropic Materials and Their Manipulations, Springer, Singapore, 2021.
[7] L. Remer, E. Mohler, W. Grill, B. Luthi, Nonreciprocity in the optical reflection of magnetoplasmas, Phys. Rev. B 30 (1984) 3277–3282.
[8] L. Zhu, S.H. Fan, Near-complete violation of detailed balance in thermal radiation, Phys. Rev. B 90 (2014), 220301.
[9] C. Khandekar, F. Khosravi, Z. Li, Z. Jacob, New spin-resolved thermal radiation laws for nonreciprocal bianisotropic media, New J. Phys. 22 (2020), 123005.
[10] Z.M. Zhang, X.H. Wu, C.J. Fu, Validity of Kirchhoff's law for semitransparent films made of anisotropic materials, J. Quant. Spectrosc. Ra. 245 (2020), 106904.
[11] S. Pajovic, Y. Tsurimaki, X. Qian, S.V. Boriskina, Radiative heat and momentum transfer from materials with broken symmetries: opinion, Opt. Mater. Express 11 (2021) 3125–3131.
[12] M.A. Green, Time-asymmetric photovoltaics, Nano Lett. 12 (2012) 5985–5988.
[13] U. Park, B. Zhao, S. Fan, Reaching the ultimate efficiency of solar energy harvesting with a nonreciprocal multijunction solar cell, Nano Lett. 22 (2022) 448–452.
[14] M. Wei, W. Wu, D. Li, H. Xu, Y. Lu, W. Song, Universal strategy for all-weather and all-terrain radiative cooling with nonreciprocal mid-infrared windows, Sol. Energy 207 (2020) 471–478.
[15] B. Zhao, Y. Shi, J. Wang, Z. Zhao, N. Zhao, S. Fan, Near-complete violation of Kirchhoff's law of thermal radiation with a 0.3 T magnetic field, Opt. Lett. 44 (2019) 4203.
[16] X.H. Wu, Z.X. Chen, F. Wu, Strong nonreciprocal radiation in a InAs film by critical coupling with a dielectric grating, ES Energy Environ 13 (2021) 8–12.
[17] X.H. Wu, The promising structure to verify the Kirchhoff's law for nonreciprocal materials, ES Energy Environ 12 (2021) 46–51.
[18] X. H Wu, R.Y. Liu, H.Y. Yu, B.Y. Wu, Strong nonreciprocal radiation in magnetophotonic crystals, J. Quant. Spectrosc. Ra. (2021), 107794.
[19] M. Liu, C. Zhao, Y. Zeng, Y. Chen, C. Zhao, C.W. Qiu, Evolution and nonreciprocity of loss-induced topological phase singularity pairs, Phys. Rev. Lett. 127 (2021), 266101.
[20] J. Wu, F. Wu, T. Zhao, M. Antezza, X.H. Wu, Dual-band nonreciprocal thermal radiation by coupling optical Tamm states in magnetophotonic multilayers, Int. J. Thermal Sciences 175 (2022), 107457.
[21] J. Wu, F. Wu, X.H. Wu, Strong dual-band nonreciprocal radiation based on a four-part periodic metal grating, Opt. Mater. 120 (2021), 111476.
[22] M.Q. Liu, C.Y. Zhao, Near-infrared nonreciprocal thermal emitters induced by asymmetric embedded eigenstates, Int. J. Heat Mass Tran. 186 (2022), 122435.
[23] J. Wu, F. Wu, T. Zhao, X.H. Wu, Tunable nonreciprocal thermal emitter based on metal grating and graphene, Int. J. Thermal Sciences 172 (2022), 107316.
[24] J. Wu, F. Wu, T. Zhao, H. Zhai, X.H. Wu, Nonreciprocal thermal radiation based on Fibonacci quasi-periodic structures, Eng. Sci. (2022), https://doi.org/10.30919/es8d575.
[25] M. Liu, S. Xia, W. Wan, J. Qin, H. Li, C. Zhao, L. Bi, C.W. Qiu, Nonreciprocal Thermal Radiation in Ultrathin Magnetized Epsilon-Near-Zero Semiconductors, 2022, 04488v1 arXiv:2203.
[26] K.J. Shayegan, B. Zhao, Y. Kim, S. Fan, H.A. Atwater, Nonreciprocal infrared absorption via resonant magneto-optical coupling to InAs, Sci. Adv. 8 (2022), eabm4308.
[27] Y. Tsurimaki, X. Qian, S. Pajovic, F. Han, M. Li, G. Chen, Phys. Rev. B 101 (2020), 1165426.
[28] S. Pajovic, Y. Tsurimaki, X. Qian, G. Chen, Large nonreciprocal absorption and emission of radiation in type-I Weyl semimetals with time reversal symmetry breaking, Phys. Rev. B 102 (2020), 165417.

[29] B. Zhao, C. Guo, C.A.A. Garcia, P. Narang, S.H. Fan, Axion-field-enabled nonreciprocal thermal radiation in Weyl semimetals, Nano Lett. 20 (2020) 1923–1927.
[30] X.H. Wu, H. Yu, F. Wu, B. Wu, Enhanced nonreciprocal radiation in Weyl semimetals by attenuated total reflection, AIP Adv. 11 (2021), 075106.
[31] J. Wu, Z. Wang, H. Zhai, Z. Shi, X.H. Wu, F. Wu, Near-complete violation of Kirchhoff's law of thermal radiation in ultrathin magnetic Weyl semimetal films, Opt. Mater. Express 11 (2021) 4058–4066.
[32] B. Zhao, J. Wang, Z. Zhao, C. Guo, Z. Yu, S. Fan, Nonreciprocal thermal emitters using metasurfaces with multiple diffraction channels, Phys. Rev. Appl. 16 (2021), 064001.
[33] X.H. Wu, C.J. Fu, Unidirectional transmission based on polarization conversion and excitation of magnetic or surface polaritons, AIP Adv. 7 (2017), 075208.
[34] X.H. Wu, C.J. Fu, Z.M. Zhang, Chiral absorbers based on polarization conversion and excitation of magnetic polaritons, ES Energy Environ 8 (2020) 5–14.
[35] M.G. Moharam, E.B. Grann, D.A. Pomment, T.K. Gaylord, Formulation for stable and efficient implementation of the rigorous coupled-wave analysis of binary gratings, J. Opt. Soc. Am. 12 (1995) 1068–1076.
[36] M.G. Moharam, D.A. Pomment, E.B. Grann, T.K. Gaylord, Stable implementation of the rigorous coupled-wave analysis for surface-relief gratings: enhanced transmittance matrix approach, J. Opt. Soc. Am. 12 (1995) 1077–1086.
[37] X. Wu, C.A. Mceleney, M.G. Jimenez, R. Macedo, Emergent asymmetries and enhancement in the absorption of natural hyperbolic crystals, Optica 6 (2019) 1478–1483.
[38] X. Wu, C.A. McEleney, Z. Shi, M.G. Jimenez, R. Macedo, Asymmetric reflection induced in reciprocal hyperbolic materials, ACS Photonics 9 (2022) 2774–2782.
[39] J. Wu, H. Li, X. Wu, C. Fu, High quality factor nonreciprocal thermal radiation in a Weyl semimetal film via the strong coupling between Tamm plasmon and defect mode, Int. J. Therm. Sci. 184 (2022), 107902.
[40] M. Shiozaki, M. Shigehara, Novel design of polarization independent multi-layer diffraction grating with high angular dispersion, SEI Technol. Rev. 59 (2005) 27–31.
[41] W. Goffe, G. Ferrier, J. Rodgers Global, Optimization of statistical functions with simulated annealing, J. Econom. 60 (1994) 65–99.

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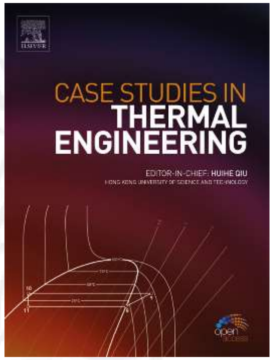

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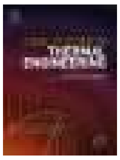

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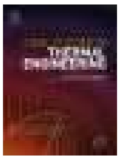

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