Using paired shutters to create irreversible light path for converting disordered thermal energy into ordered energy such as electrical energy

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Abstract

Based on previous research on generating electricity through the irreversible phenomena of light caused by paired rotating gratings, we propose an alternative method due to the excessively high rotational speeds required by the gratings. This new approach involves using paired shutters to create irreversible light phenomena, achieving the same goal of converting disordered thermal energy into ordered electrical energy, and making the method feasible with current technological capabilities. The method employs two black bodies equipped with shutters. In the light path of one side, the shutter opening and closing timings differ by the time it takes for light to travel between the two shutters, allowing light to pass through in one direction. Conversely, in the opposite light path, the shutter timings are such that when the shutter at the source end is open, the light reaching the other end finds the shutter closed, preventing the light from passing through. This creates an irreversible path for the light. In our paper, we explored various structural designs and theoretically demonstrated that this approach is achievable with existing technology. Moreover, since the direction of light travel is perpendicular to the physical movement of the shutters, the system can operate without kinetic energy loss due to light pressure, allowing for frictionless and sustainable operation. Thus, this method has the potential to become an environmentally friendly energy source.

Keywords: Paired shutters, Irreversible light phenomena, Disordered thermal energy, Ordered electrical energy, Sustainable energy source

Symbols:

c	Speed of light,
L	Distance between the polarizers or gratings,
d_1	Transparent slot width,
d_2	Opaque line width,
ℓ	Total length of the grating region,
t_ω	Rotational period,
Δt	Tim interval,

1 Introduction

Previous research explored the creation of irreversible light phenomena using rotating polarizers [1]. This paper aims to address the practical challenges of implementing the earlier study. The significance of this research lies in addressing the issue of global warming and climate change caused by carbon dioxide, which leads to extreme weather and natural disasters worldwide. Meeting human energy demands without increasing carbon dioxide emissions has become crucial. Currently, many countries are developing nuclear energy to achieve carbon-free energy sources. However, nuclear energy poses the problem of long-term waste management, passing the burden onto future generations.

In this context, we have considered various carbon-free energy sources, and the concept presented here is one of them. Our design involves creating a temperature difference spontaneously without energy consumption, allowing the conversion of thermal energy into electrical energy. According to current theories, when two objects at the same temperature emit thermal radiation toward each other, the intensity of radiation absorbed and emitted at the same wavelength will be equal, without external interference. Therefore, in the absence of external interference, the temperatures will not change due to mutual radiation emission and absorption.

We create an interference environment where the ratio of radiation at the same wavelength reaching each object differs, leading to a condition where light is not completely reversible. Theoretically, this results in different emission and absorption rates for each object, creating a temperature difference that can be used for power generation. Theoretically, this system can operate without energy consumption, providing a net energy output, and has the potential to become a viable, carbon-free, environmentally friendly energy source.

2 Methods and Theoretical derivation

2.1 Replacing the Physical Polarizers in Previous Work [1] with Electronic Polarizers

Light is a high-frequency electromagnetic wave. The principle of polarizers is to utilize the property of unidirectional conductivity, allowing only the component of light's electric field perpendicular to the conductive direction to pass through, while blocking the component parallel to it. With current technology, thin-film transistors (TFTs) can be fabricated on glass, designed to conduct in one direction and controlled by voltage. When a voltage is applied, these transistors exhibit unidirectional conductivity and polarizing effect. Applying a reverse voltage cancels this property, removing the polarizing effect, thus eliminating the need for polarizer rotation.

The first setup for electronic polarizers involves switching between fully transparent and polarizing states. When unpolarized light passes through the polarizing state, half of its intensity is blocked (absorbed) due to a phase shift of $\pi/2$. Here, the phase angles of the electronic polarizers near black body A and black body B are the same. By setting the polarizers to switch with a period of 4L/c, being on for 2L/c and off for 2L/c, where L is the distance between the polarizers and c is the speed of light, and by setting the polarizer near black body A to lead by L/c in time relative to the polarizer near black body B:

Radiation from black body A towards B, in the polarized state at A with an intensity of 1/2, reaches B's polarizer in the same phase angle and passes through. Unpolarized light at A reaches B's polarizer in the non-polarized state, passing through completely. Therefore, on average, 3/4 of A's radiation reaches B.

Radiation from black body B towards A, in the polarized state at B with an intensity of 1/2, reaches A's polarizer in the non-polarized state, passing through completely. Unpolarized light at B reaches A's polarizer in the polarized state, with only 1/2 intensity passing through. Therefore, on average, 1/2 of B's radiation reaches A.

This asymmetry in the radiation absorption rates between A and B creates a temperature difference.

The second setup switches between fully opaque and polarizing states. Using the same setup:

On average, 1/4 of A's radiation reaches B, while B's radiation reaching A is zero, also creating a temperature difference.

These two types of electronic polarizers can be alternated and combined in various configurations to create temperature differences, and further details are not discussed here.

2.2 Replacing Electronic Polarizers in '2.1' with Electronic Shutters

Similarly, thin-film transistors (TFTs) are fabricated on the surface of glass, but in this configuration, they conduct in all directions when a voltage is applied, blocking the light. When a reverse voltage is applied, they become non-conductive in all directions, allowing light to pass through. Using a timing sequence similar to that in '2.1', black body A can have an average of 1/2 of its radiation reaching black body B, while radiation from black body B reaching black body A is zero. This creates an irreversible path for light, generating a temperature difference that can be used for power generation.

Furthermore, electronic shutters and electronic polarizers can be combined in various configurations, creating temperature differences between the two bodies in multiple ways. Detailed descriptions of these configurations are not included here.

2.3 Using Two Opposing Moving Gratings to Form a Rapid Light Switch

The gratings are designed with a transparent slot width of d1 and an opaque line width of d2. By moving the gratings at a speed of $\left(\frac{d_1}{2}+\frac{d_2}{2}\right)/\left(\frac{4L}{c}\right)$, they can replace the electronic light switches described in '2.2'. The operating principle is illustrated in Figure 1. In this figure, one grating, shown in green, moves from left to right, while the other grating, shown in blue, moves from right to left. At the top of the figure, the transparent sections of the two gratings overlap, allowing light to pass through. As time progresses (moving from top to bottom of the figure), the transparent sections overlap with the opaque sections of the opposing grating, blocking the light.

As shown in the figure, when each grating moves only by $\left(\frac{d_1}{2}+\frac{d_2}{2}\right)$, they can switch between the transparent and opaque states, effectively replacing the electronic light switches in '2.2'. In a vacuum, high-speed rotating gratings can be set to rotate with constant velocity due to inertia without friction, resulting in no energy loss. This enables spontaneous temperature differences without energy consumption, allowing the conversion of thermal energy into electrical energy without energy loss.

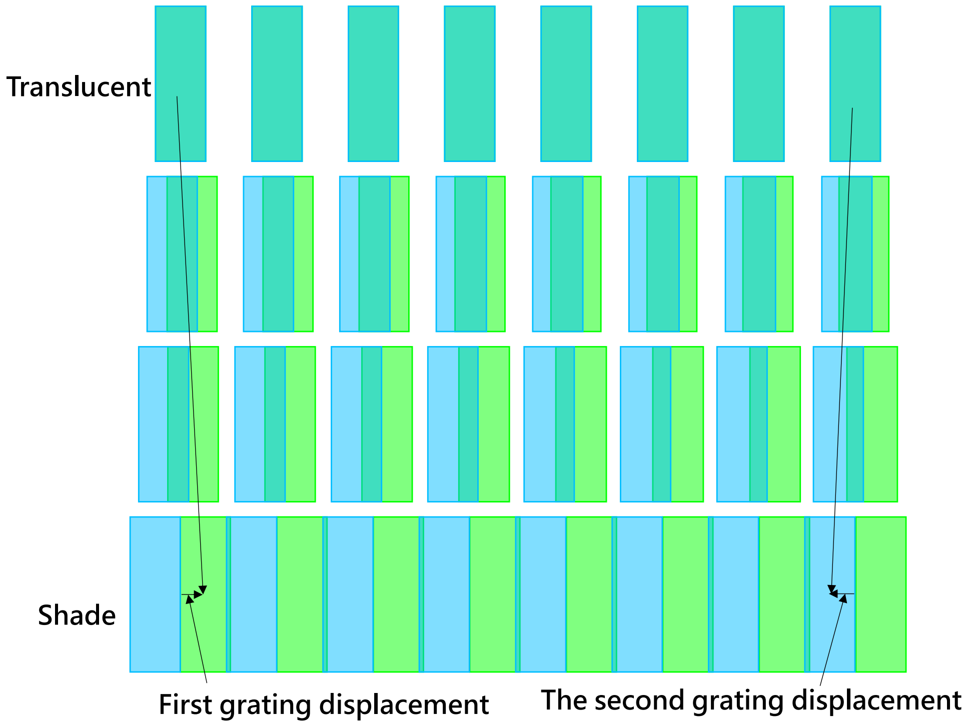

Figure 1: Schematic of a rapid light shutter made from a pair of opposing moving gratings.

2.4 Two Circular Gratings with a Difference of One Slot, Rotating in Opposite Directions

There are two gratings, one with n light-transmitting slots and the other with $n+1$ light-transmitting slots, as shown in the right part of Figure 2. The grating with n slots is represented in green, and the one with $n+1$ slots is represented in blue. This setup results in a position difference where one side allows light to pass through while the other does not. When the gratings move in opposite directions and one grating moves by $\ell/2(2n+1)$ and the other by $-\ell/2(2n+1)$, where ℓ is the total length of the grating region, the light-transmitting area shifts by $\ell/2$. As shown in the right part of Figure 2, the light-transmitting area moves rapidly with minimal displacement of the gratings.

By arranging the gratings in a circular configuration, a smaller rotational speed can achieve rapid movement of the light-transmitting position. Thus, with a rotational period of t_ω, the light switch's transmitting position rotates quickly, completing one full rotation in $t_\omega/(2n+1)$. As illustrated in the left part of Figure 2, when the gratings are arranged in a circular configuration, the light-transmitting area rotates quickly. This light switch can be applied to the various methods previously described.

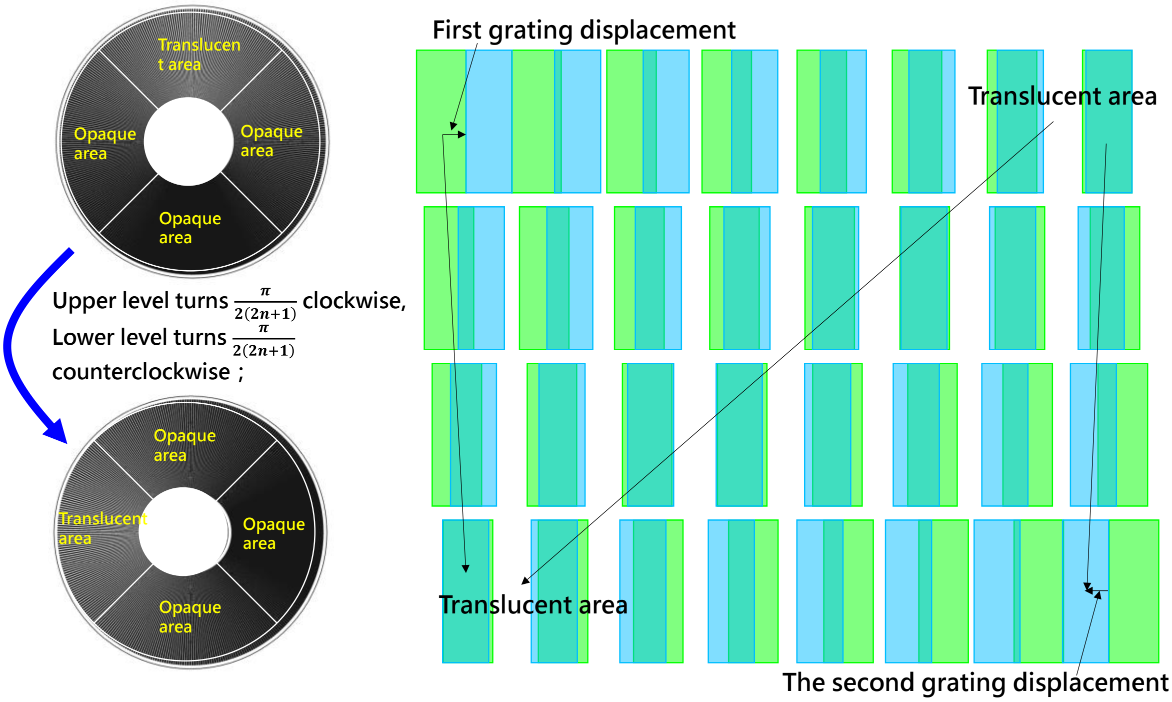

Figure 2: Two gratings, one with n light-transmitting slots and the other with $n+1$ light-transmitting slots, achieve rapid movement of the light-transmitting area with minimal displacement, allowing for fast rotation of the light-transmitting area with a low rotational speed.

2.5 Using a Single Set of Gratings in a Structure with a Return Path

The rapidly rotating gratings described in '2.4' can achieve the effects of several previously mentioned methods with just one set of gratings in a structure with a return path. As illustrated in Figure 3, the thermal radiation in region A, when the grating in front of region A is transparent, travels through the light-guiding column (shown in blue) along the red path. After a time interval Δt, it reaches B1, where the grating's transparent position has shifted to in front of B1, allowing it to pass through and heat region B1. During this time, the thermal radiation from region B1 passes back through the grating along the purple path, and after Δt, reaches region A. However, the grating's transparent position has shifted to in front of B2, making the grating in front of A opaque, thus preventing heating of region A. This setup causes region A to heat region B1 while B1 cannot heat region A, making B1 increasingly hotter and A cooler.

For a two-stage series, the heat from B1 can transfer to B2, and B2 can heat region C using the same principle, doubling the temperature difference between A and C. If the light-guiding column's length is 20 meters, a round trip totals 40 meters. With a refractive index of approximately 1.5 for glass, the round trip time is Δt = (20m × 2 × 1.5) / c = 2×10^{-7} seconds. Considering the peak wavelength of thermal radiation at room temperature is about 1.7×10^{-5} meters, the widest opening of the grating should be 3.4×10^{-5} meters, and the outer radius of the grating should be 0.2 meters. Simulations show the optimal spacing for the widest openings to be $3.4 \times 10^{-5} \times 1.8 = 6.12 \times 10^{-5}$ meters, with a step width of the grating openings of $s = 9.52 \times 10^{-5}$ meters.

To rotate the transparent section by an angle of π/2 in 2×10^{-7} seconds, the angular velocity of the grating must be π/4(2n + 1)Δt = π/2(2n + 1)Δt, where n = 2πr / s = (2π × 0.2) / (9.52×10^{-5}) = 13200, giving an angular velocity of 60 / 2π × π/2(2n + 1)Δt = 15 / (2n + 1)Δt = 15 / (26401 × 2×10^{-7}) = 2841 RPM.

Simulations indicate the efficiency of the grating method is approximately one-third of that of electronic polarizers. However, gratings can operate at higher temperatures, potentially 300 degrees higher than electronic polarizers, increasing efficiency by a factor of 10. Thus, the overall efficiency could be approximately 3.3 times higher than that of electronic polarizers. The rotational speed of 2841 RPM is feasible, and the grating's widest opening of 340 micrometers and narrowest opening of about 150 micrometers are achievable with existing technology. It is worth noting that the two gratings can operate at different speeds, or one can remain stationary.

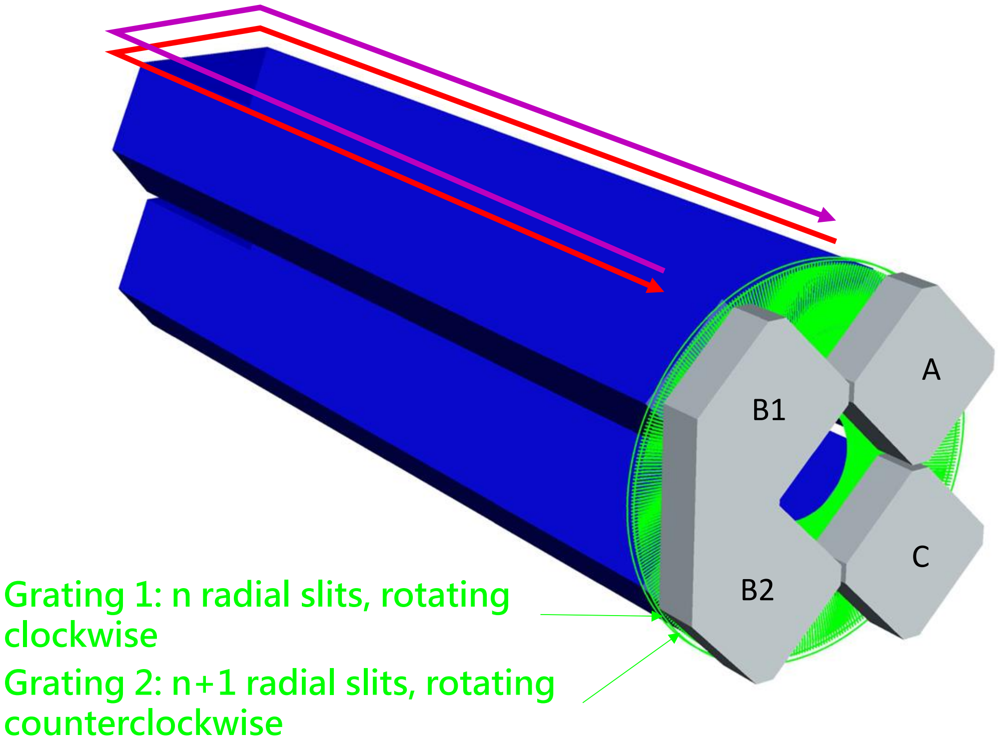

Figure 3: A schematic diagram of a single set of counter-rotating gratings combined with a dual-path light return structure. Region A heats region B1, while region B2 heats region C.

2.6 Maintaining Two Gratings in Close Proximity Using Air Cushions or Repulsive Magnets

As mentioned in sections '2.3' to '2.5', the two gratings moving in opposite directions need to be precisely aligned and must operate at a very small distance to prevent light leakage. Given the narrow width of the grating slits, the distance between the two gratings must be maintained at less than 10 micrometers to minimize light leakage.

When the grating material is highly rigid, maintaining a distance of less than 10 micrometers is feasible with peripheral driving mechanisms, but this introduces significant friction. To reduce friction, the drive must be placed centrally. However, maintaining a sub-10-micrometer gap with central driving mechanisms during rapid rotation is challenging.

Current technology can achieve such small gap maintenance using air cushions. However, the presence of air cushions introduces air resistance, resulting in energy loss. To eliminate air resistance, the system must operate in a vacuum environment.

In a vacuum, maintaining a small gap can be achieved using magnetic levitation, as shown in Figure 4. By positioning magnets with an accuracy of less than 50 micrometers on the periphery, magnetic levitation can keep the grating gap under 10 micrometers.

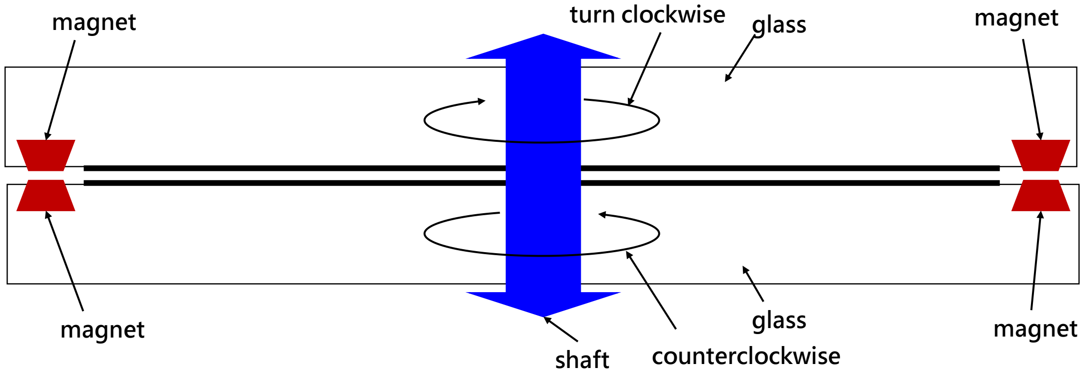

Figure 4: Schematic diagram illustrating the use of repulsive magnets to create a magnetic levitation environment, allowing two gratings to rotate in close proximity.

2.7 Enhancing Light Transmission with Micro-Optical Structures on Gratings

Referencing Figure 5, the flat structure on the left allows less than 1/2 of the light to pass through. However, the example on the right shows that when incident light approaches the grating almost perpendicularly, more than 1/2 of the light can pass through the slits. This design can be applied to previous methods to enhance light transmission and increase the achievable temperature difference.

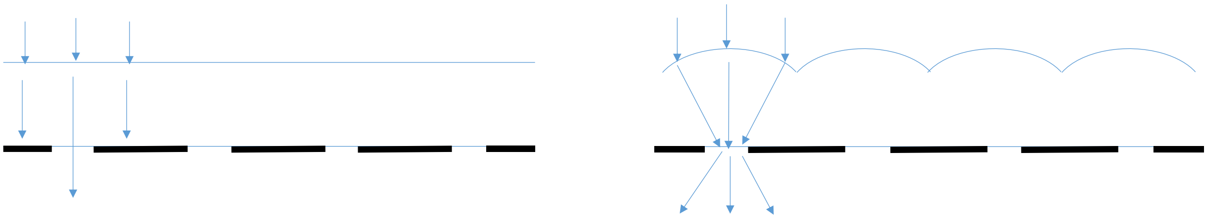

Figure 5: Schematic diagram of the backside shape of a grating. The left side depicts a flat structure without microstructures, while the right side illustrates a design with microstructures to enhance light transmission.

2.8 Altering Reflection Angles with Microstructures on Grating Reflective Surfaces

Referencing Figure 6, in the previously shown example, when radiation from Blackbody B passes through the adjacent grating and heads toward the grating near Blackbody A, the latter grating is in a closed state. To reduce light loss, the optimal solution is for the grating near Blackbody A to reflect the incident light back. However, if this reflected light returns to the grating near Blackbody B after L/c time, it will face a closed grating as well. If the grating near Blackbody B reflects the light back towards Blackbody A, the light will take another L/c time to reach the grating near Blackbody A. Since this light has traveled for 3L/c time from Blackbody B, it will encounter the grating near Blackbody A in an open state, allowing a higher proportion of the light to reach Blackbody A. This would increase the proportion of radiation from Blackbody B to Blackbody A, negating the intended design of having more radiation from A to B and less from B to A. As illustrated, microstructures on the grating near Blackbody A can deflect incident light by 60 degrees. This deflection means the light will take an additional L/c time to return to the grating near Blackbody B, encountering it in an open state and returning to Blackbody B with a higher proportion, thereby enhancing the system's design effectiveness.

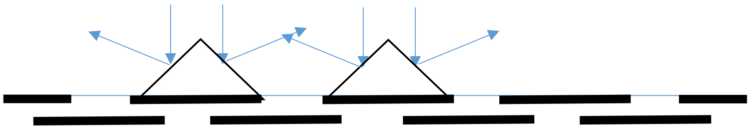

Figure 6: Microstructures on the grating surface deflect reflected light, requiring additional time to pass through the waveguide.

3 Discussion

In previous research, a concept was introduced to create an irreversible optical system by leveraging the time delay caused by the speed of light, potentially breaking the constraints of the second law of thermodynamics . However, due to the extremely high speed of light, the rotational speed of the proposed rotating polarizer would also need to be extremely high. This makes it challenging to achieve the necessary rotational speed if the two black bodies are not very far apart. On the other hand, if the two black bodies are far apart, the long-distance light transmission losses make practical implementation difficult. Therefore, we propose a structural design based on the same principle but realizable with current technology. From the preceding analysis, it can be confirmed that this concept is feasible with existing scientific and technological capabilities, greatly increasing the practicality of using this method to develop environmentally friendly energy systems.

4 Conclusion

The previous study provided a conceptual possibility of surpassing the second law of thermodynamics. Our proposed rotating grating system utilizes feasible current technology to achieve the theoretical goals of the earlier paper, representing a significant advancement. This progress substantially enhances the potential for realizing environmentally friendly energy systems using this method.

Declarations

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Competing interests

The author declares that there are no conflicts of interest.

***Availability of data and material*:** Not applicable

***Authors' contributions*:**

Kuo Tso Chen designed the study, performed the experiments, analyzed the data, and wrote the manuscript.

Ethics approval

I confirm that the manuscript has been approved by the author for publication. I would like to declare that the work described herein is original research and that it has not been published previously.

***Code availability*:** Not applicable

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1. Kuo Tso Chen, “An Exception to the Carnot Theorem: the Temperatures of Two Black Bodies at Equilibrium Differ Due to the Influence of a Pair of Rapidly Rotating Polarizers”, https://vixra.org/abs/2406.0042.