FARADAY ISOLATORS AND THE SECOND LAW OF THERMODYNAMICS

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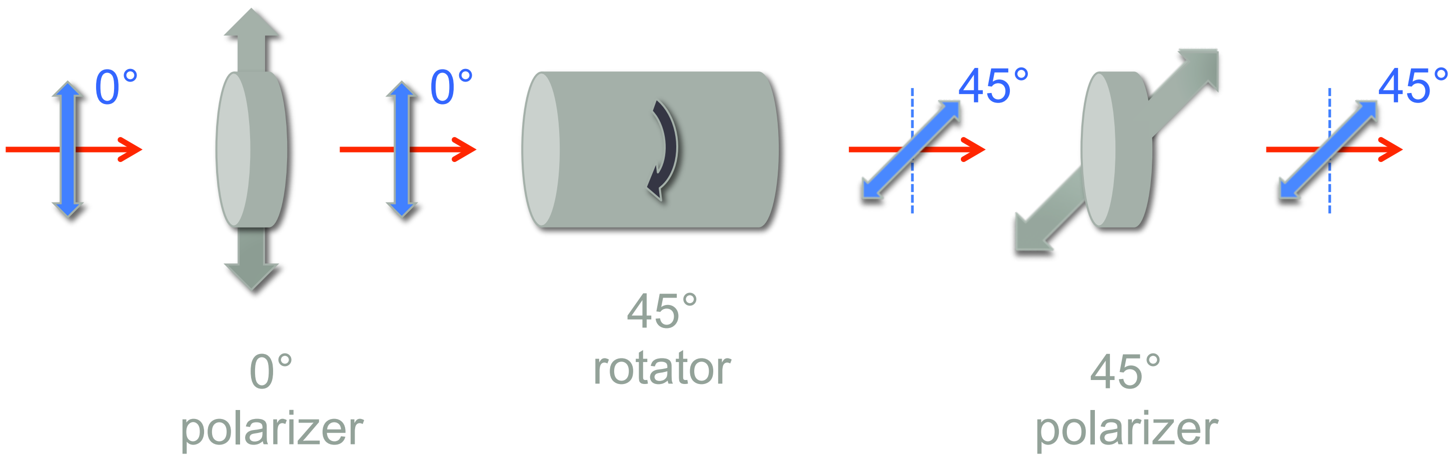
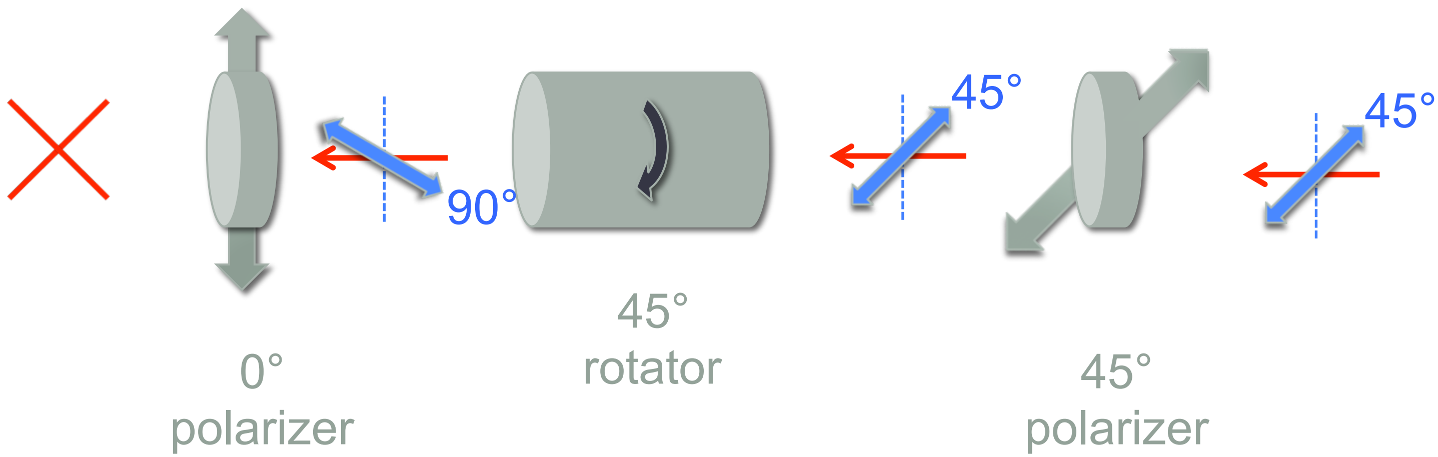
A Faraday isolator is an optical diode:

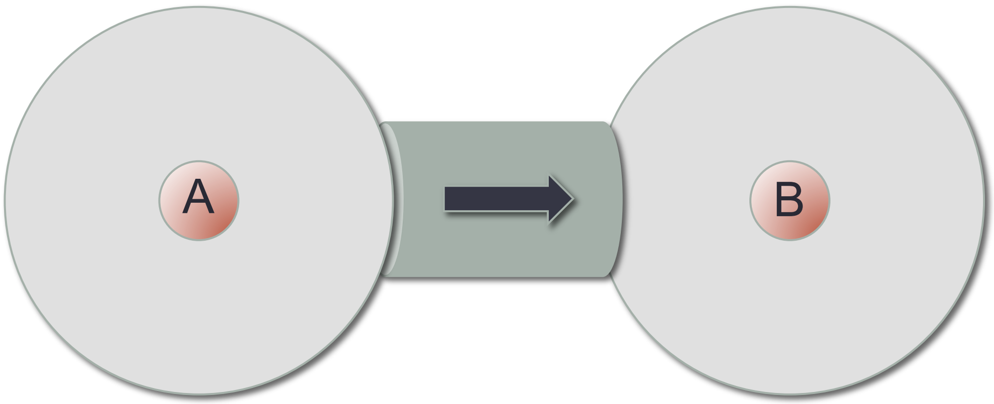


Rightward beam gets transmitted.



Leftward beam gets blocked.

Two blackbody samples inside integrating spheres connected by a Faraday isolator:



Apparently radiation flows from A to B but not from B to A,
in which case A spontaneously cools down and B heats up.

That would be inconsistent with the second law of thermodynamics!

One suggested fix: The optical diode only works for certain polarizations of light. The other polarizations mess up the effect.

Not necessarily: Make the two ends of the isolator back-reflect the rejected polarizations.
Also make the integrating spheres depolarizing to keep recreating the passed polarization.
Together those maintain the one-way flow.

Another suggested fix: The optical diode only works for one wavelength of light. The other wavelengths mess up the effect.

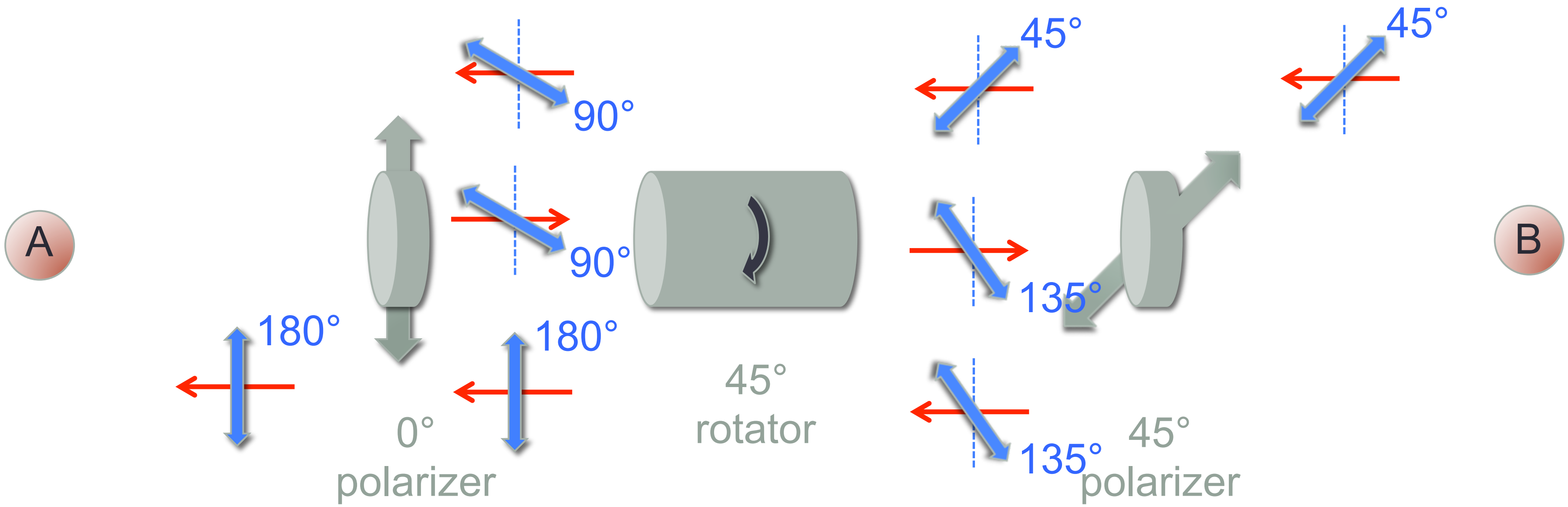
Not necessarily: Put spectral coatings on both ends of the isolator to pass that wavelength and reflect all others. As the samples absorb and re-emit, they recreate the passed wavelength. These effects again maintain the one-way flow.

Everything stated so far is true except for the apparent claim that net radiation flows from A to B.

What actually prevents that from happening?

Hint: Consider more carefully what happens to light traveling from B to A.

If polarizers back-reflect rejected polarizations:



Then light *does* get from B back to A!

Wait a minute: That would mean Faraday isolators do NOT work as optical diodes!

Right, so we cannot *back-reflect* the rejected polarizations. Real isolators can instead *absorb* them.

But that will *heat up* the polarizers, causing blackbody emission that saves the second law.

Alternatively we can reflect the rejected polarizations out an exit port, to avoid heating the polarizers.

But then outside light can enter backward through that port, again saving the second law.

Questions?

For a longer, written discussion of this presentation:
usna.edu/Users/physics/mungan/_files/documents/Scholarship/FaradayIsolators.pdf

Here are two more issues:

1. "Optical reversibility" is sometimes stated this way. If you reverse the direction of propagation of all outgoing light rays, you recreate the incident beam. A Faraday isolator violates that. What is a correct statement of the principle? (Hint: reverse the flow of time.)

2. How does a magnetic rotator work? Why does it rotate the polarization of light in the same direction regardless of which way the light passes through it? (Hint: a linearly polarized beam can be written as a mix of cw and ccw circularly polarized beams.)

References

Wien, "Les lois théoriques du rayonnement: Rapports présentés au Congrès International de Physique" (Paris, 1900) Vol. 2, p. 29

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Wood, "Magnetic rotation and the second law of thermodynamics," *Physical Optics* (NY, Macmillan, 1929) 2nd ed., p. 500