High performance Thermophotovoltaics
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Thermophotovoltaic (TPV) system

- Kirchhoff’s law of thermal radiation:
  \[ \varepsilon(\lambda) = A(\lambda) = 1 - R(\lambda) - T(\lambda) \]

- Short-circuit current \( J_{SC} \) and open-circuit voltage \( V_{OC} \)
  \[ J = J_{SC} - I \]

\[ 2qc \int_{0}^{\infty} \frac{\varepsilon(\lambda)EQE(\lambda)}{\lambda^{4} \left( \exp \left( \frac{hc}{\lambda kT_{e}} \right) - 1 \right)} \cdot \frac{1}{\exp \left( \frac{qV}{nkT_{e}} \right) - 1} \cdot J_{sc} \cdot e^{-Eg/kT_{e}} \text{[exp(qV/mkT_{e}) - 1]} \]

TPV system efficiency estimation

- Tungsten has the highest estimated efficiency of 35.2% at 1573 K with \( E_g = 0.7 \text{ eV} \).

- Molybdenum has the highest estimated efficiency of 35.12% at 1573 K with \( E_g = 0.7 \text{ eV} \).

- Partially transmissive dielectric mirror
  \[ \lambda = 1.47 \mu \text{m} \]

- Exponentially-chirped period
  \[ n(0) = 1.83 \]

- Fiber reflectance
  \[ \text{Reflectance} \]

- Fiber emittance
  \[ \text{Emittance} \]

- Rare earth emitter (ErAG)
  \[ n = 1323 \text{ K} \]
  \[ n = 1573 \text{ K} \]

- AR+rugate filter
  12.05
  18.63
  1/1

- Q-match+rugate filter
  15.34
  22.58
  3/21

- Chirped filter+shifted rugate filter
  25.55
  33.89
  Chirped 26/21

- Chirped filter only
  25.46
  32.94
  Chirped 26/21

Integrated photonic crystal selective emitter (IPSE) design

Integrated photonic crystal selective emitter simulation

Conclusions

- TPV system Conversion Efficiencies above 42% can be reached by appropriate engineering.
- Integrated filter photonic crystal emitters and rare earth emitters can significantly suppress the parasitic loss at long wavelengths that causes the major losses in TPV conversion systems.