EC 4210 Solutions

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Assignment 8

21.1. Consider a detector with an idealized spectral response as shown in Fig 1. The blackbody

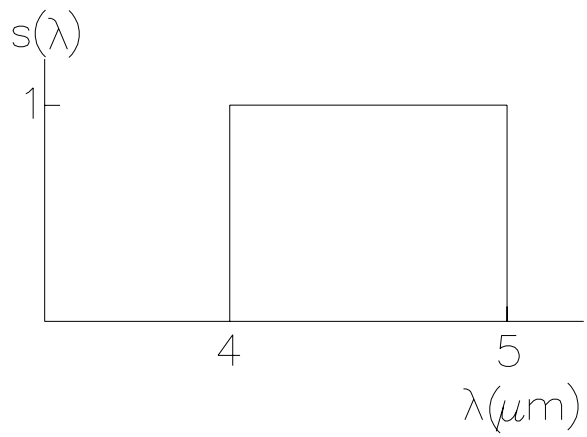

Figure 1: Spectral response for Problem 1.

detectivity D^*_{BB} is found to be 9×10^{10} cm·Hz$^{1/2}$·W^{-1} when measured with a 500K blackbody.

a. Calculate the conversion factor $1/\xi$.

b. Calculate the value of D^*_{pk}.

c. Sketch a plot of $D^*(\lambda)$ vs. λ for this hypothetical detector.

<u>Solution:</u> a. We want to compute the conversion factor $1/\xi$.

$$\frac{1}{\xi} = \frac{W}{\int_0^\infty s(\lambda) W_\lambda(\lambda)\, d\lambda} = \frac{W}{\int_4^5 1 \cdot W_\lambda\, d\lambda} = \frac{W}{\int_0^5 1 \cdot W_\lambda\, d\lambda - \int_0^4 1 \cdot W_\lambda\, d\lambda} \tag{1}$$
$$= \frac{W}{(0.17 - 0.072)\, W} = \frac{1}{0.098} = 10.2\,.$$

(Note: My evaluation of the definite integrals in the denominator was done using a blackbody slide-rule.) You should have used the Fig. 19.4 on page 283.

b. The value of $D^*_{\rm pk}$ is found from

$$D^*_{\rm pk} = \frac{1}{\xi} \cdot D^*_{\rm BB} = (10.2)(9 \times 10^{11}) = 9.18 \times 10^{11}\ {\rm cm} \cdot {\rm Hz}^{1/2} \cdot {\rm W}^{-1}\,. \tag{2}$$

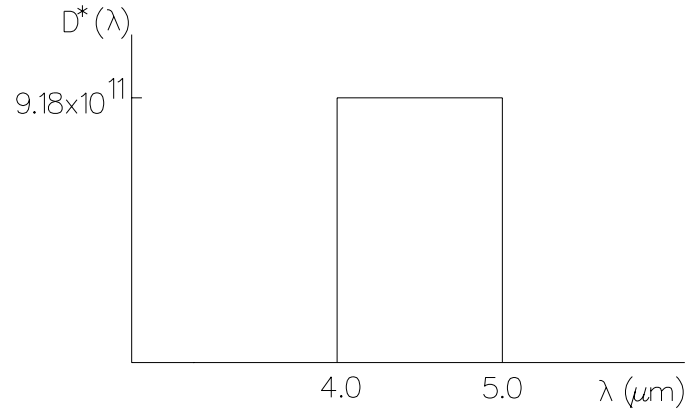

Figure 2: Spectral $D^*(\lambda)$ for Problem 1c.

c. The plot of $D^*(\lambda)$ is seen in Fig. 2.

21.2. Consider a 1 mm x 1 mm detector that is tested with a 500K blackbody source with a 1 cm^2 emitting aperture. The source-to-detector distance is 1 m. The detector produces 8 nV of output noise voltage into a 1 kHz bandwidth and 40 nV of output signal (rms) voltage.

a.Calculate the on-axis rms irradiance if a square-wave chopper is used at 800 Hz.

b. Calculate the detector responsivity.

c. Calculate the noise equivalent power.

d. Calculate the noise equivalent irradiance.

e. Calculate the detectivity D.

f. Calculate D^*_{BB} of the detector.

Solution: a. The rms irradiance H is

$$H = \frac{0.45\sigma T^4 A_s}{\pi d^2} = \frac{(0.45)(5.67\times10^{-12})(500)^4(1)}{\pi(100)^2} = 5.08\times10^{-6}\ \mathrm{W\cdot cm^2}\,. \tag{3}$$

b. The detector responsivity $\mathcal{R}$ is

$$\mathcal{R} = \frac{V_{\mathrm{rms}}}{HA_d} = \frac{40\times10^{-9}}{(5.08\times10^{-6})(1\times10^{-2})} = 0.787\ \mathrm{V\cdot W^{-1}}\,. \tag{4}$$

c. The NEP of the detector is

$$\mathrm{NEP} = \frac{HA_d}{\frac{V_s}{V_N}} = \frac{(5.08\times10^{-6})(1\times10^{-2})}{\frac{40\times10^{-9}}{8\times10^{-9}}} = 1.016\times10^{-8}\ \mathrm{W}\,. \tag{5}$$

d. The NEI of the detector is

$$\mathrm{NEI} = \frac{\mathrm{NEP}}{\mathrm{A_d}} = \frac{1.016 \times 10^{-8}}{1 \times 10^{-2}} = 1.016 \times 10^{-6}\ \mathrm{W \cdot cm^{-2}}\,. \tag{6}$$

e. The D of the detector is

$$\mathrm{D} = \frac{1}{\mathrm{NEP}} = 9.87 \times 10^{7}\ \mathrm{W^{-1}}\,. \tag{7}$$

f. The D^*_{BB} of the detector is

$$D^*_{\mathrm{BB}} = D\sqrt{A_d B} = \frac{\sqrt{A_d B}}{NEP} = \frac{\sqrt{(1 \times 10^{-2})(1 \times 10^{3})}}{1.016 \times 10^{-6}} = 3.11 \times 10^{8}\ \mathrm{cm \cdot Hz^{1/2} \cdot W^{-1}}\,. \tag{8}$$

21.3. An infrared detector and its test setup have the following properties:

Parameter	Value
η	90%
$\mathrm{f_{chop}}$	10 kHz
Size	1 mm x 1 mm
B	500 Hz
D^*_{BB}	3×10^{9} cm$\cdot$W$^{-1}\cdot\sqrt{\mathrm{Hz}}$

When irradiated by a constant-power beam, the measured voltage signal-to-noise ratio is 10 dB. Calculate the irradiance of the beam at the chopper (assuming that the detector is located immediately behind the chopper in the experiment).

Solution: We begin by finding the converted signal-to-noise ratio,

$$\frac{V_s}{V_n} = 10^{\frac{10}{20}} = 3.16\,. \tag{9}$$

The formula for D^*_{BB} can be inverted to solve for H_{rms},

$$D^*_{\mathrm{BB}} = \left(\frac{V_s}{V_n}\right)\left(\frac{\sqrt{A_d B}}{H_{\mathrm{rms}} A_d}\right)\,, \tag{10a}$$

so

$$H_{\mathrm{rms}} = \left(\frac{V_s}{V_n}\right)\left(\frac{\sqrt{A_d B}}{D^*_{\mathrm{BB}} A_d}\right) = 2.36 \times 10^{-5}\,. \tag{10b}$$

The dc irradiance in front of the chopper is then found as

$$H = \frac{H_{\mathrm{rms}}}{0.45} = 5.24 \times 10^{-5}\ \mathrm{W \cdot m^{-2}} = 0.524\ \mathrm{W \cdot cm^{-2}}\,. \tag{11}$$