Detection of Light: Exercise 8

Set: Thurs 30th Mar 2017,
Due: Thurs 6th Apr 2017

1 Heterodyne Performance [10 marks]

We would like to design a heterodyne receiver for observations at $\lambda = 210\,\mu$m. This incorporates a cylindrical diode photomixer made from HgCdTe ($\kappa = 10$) of diameter 85 μm and depletion region of width 1.5 μm, which may be modelled as a simple RC circuit. The input impedance of the amplifier is $140\,\Omega$.

a Calculate the IF bandwidth of the receiver, assuming this is limited by the frequency response of the mixer.

[3 marks]

b Calibration observations are made of two blackbodies with temperatures $T_1 = 3000$ K and $T_2 = 200$ K, for which the receiver measures 3.7 V and 1.2 V respectively.
i) Calculate the effective noise temperature T_N of this receiver.
ii) In which noise regime is the receiver operating?
iii) Hence calculate the RMS amplifier noise current of our heterodyne receiver.

[3 marks]

c We now wish to compare the performance of our receiver with that of a bolometer operating in the background limit, with $\eta = 0.55$, operated through a spectral band of width 15% of the central frequency.

i) Calculate the fractional S/N achieved by our heterodyne receiver with respect to the bolometer: which one performs better under the given conditions?
ii) At what spectral bandwidth Δv would the two detectors provide equal performance, and what spectral resolution does this correspond to?
iii) What is the critical assumption under which this trade-off is valid?

[4 marks]