PHYS-E055102, Low Temperature Physics, Exercise 3 DL 28.09.2022

1. In a dry dilution cryostat, a pulse tube can be used for precooling down to 4 K. Typical cooling power of a pulse tube at 4 K is 0.5 W. Calculate how many deoxidized copper wires (radius 1 mm, length 1 m) one can have between room temperature and the 4 K plate of the cryostat. How about constantan wires? How large is the electron contribution of the total heat conductance?

2. Between the inner and outer walls of a dewar are n layers of super insulator with emissivity ε (reflective thermally non-anchored radiation shield). Determine the heat leak into the dewar due to thermal radiation.

   Hint: For simplicity, you can assume that the thickness of the insulating wall is small compared to the radius of the dewar, i.e. the surface area of each layer is approximately equal.

3. Consider two coaxial cylinders where a cylinder with surface area A_1, emissivity ε_1, and temperature T_1 is inside the other with parameters A_2, ε_2, and T_2. Derive the expression for the heat transfer between the cylinders. What happens at the limits $A_1 = A_2$ and $A_1 \ll A_2$?

   Hint: It can be useful to think that cylinder surfaces consist of independent point-like radiation sources that radiate to all directions.

4. A sample at low temperature ($T \ll 1\,\mathrm{K}$) is being photographed by a CCD-sensor at 60 K, see Fig. 1. Calculate the heat leak (thermal radiation) from the camera to the sample when there is

   a) no window between them.

   b) 5 mm CaF_2 window.

   c) 2 mm sapphire window.

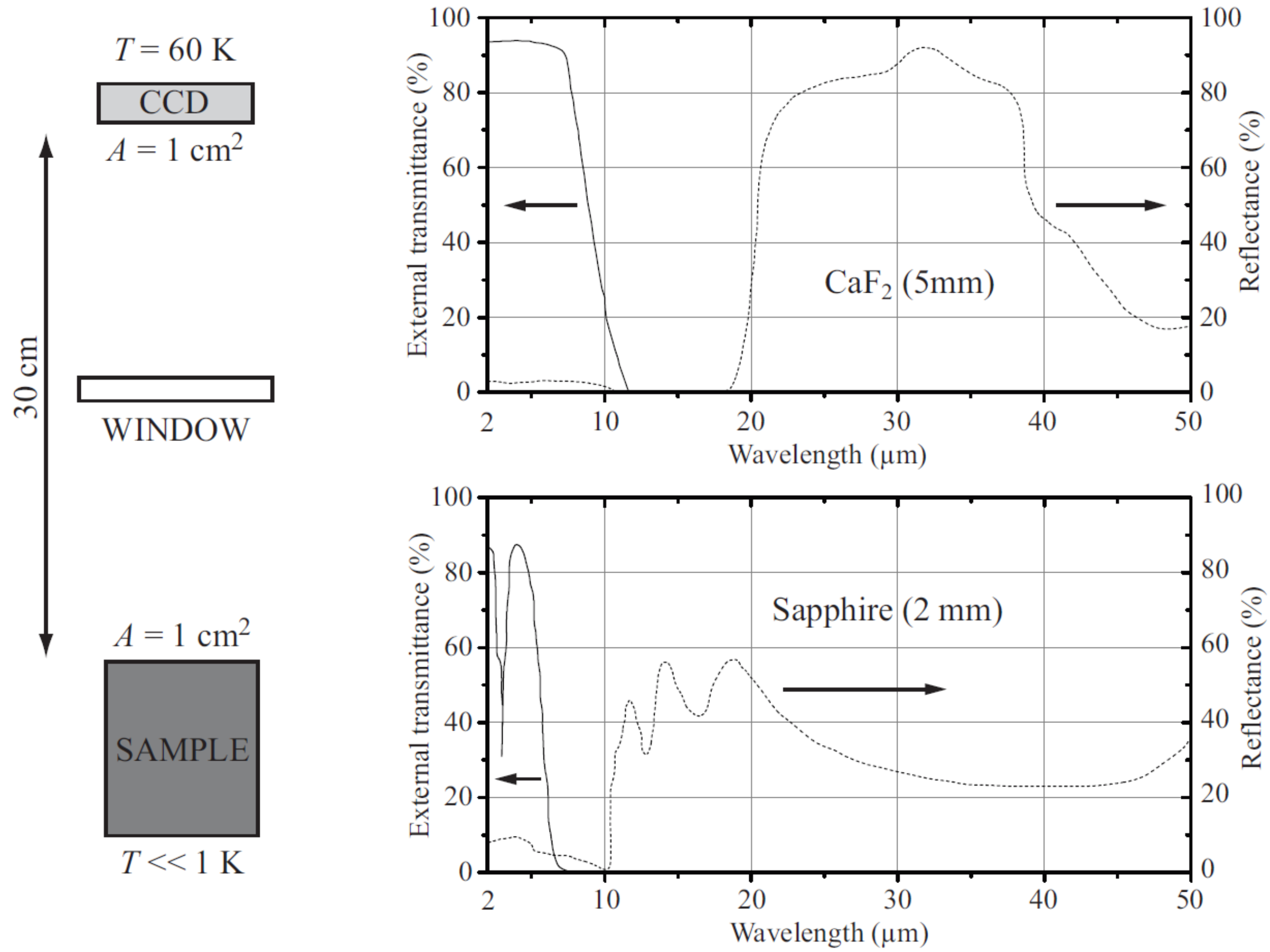

Figure 1: Schematic of the imaging setup and transmittance properties of CaF_2 and sapphire.