The infrared photon trap

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Definition of the problem

- We have learned during the visit to Aarhus university on Sunday in the talk by Soren Pape Moller, that negatively charged Helium can change its charge state (rather loosely bound electron) by the Lorenz transformed thermal radiation in the beampipe. This leads to beam loss (then the electron is gone)
- For comparison: Green light has en energy of about 2 eV (0.5 micron) corresponding to the temperature of the surface of the sun.(6000 Kelvin)
- At room temperature 300 Kelvin we have thus 0.1 eV or 10 micron wavelenght in the maximum of the emission (Wien´s law)

The classical solution and questions

- Assuming that the surface of the beampipe is a black body the logical approach is to cool the beampipe to some rather low temperature, which is possible but tedious.
- But is this statement really true, i.e is the beampipe really a black body in the region of 10 micron ?
- The answer is no and yes: A smooth stainless steel surface has a reflectivity of more than 95% (with gold coating more than 99%) for 10 micron (emissivity accordingly 5 and 1% respectively)
- But looking into a LONG beampipe at room temp. it will appear black due to the many multiple reflections a light beam has done coming from far away through this pipe.

A potential new solution

- Why not just place a cryogenically cooled, but really BLACK (in the 10 micron range)short section (say 50 cm length) every say 5 to 10 meter?
- If it works it would save a lot of money and simplify the design, since one could place all kind of equipment (magnets , diagnostics etc) in the normal conducting sections in between.
- We know from basic principles that only losses and lossy structures can emit noise .Reactances do NOT produce noise (justification for the parametric amplifier)

A microwave equivalent circuit (1)

- A simple equivalent circuit could be a cold (cryo) microwave load connected to the low loss transmission line (say 0.5 dB loss) of a certain length but the transmission line (waveguide is at room temperature).
- How to calculate the noise-temperature of a network of lossy elements (load , waveguide) which are at inhomogeneous temperature?
- Just by using the reciprocity and superposition theorem (c.f. B. Schiek , Rauschen in Mikrowellenschaltungen or same author: Hochfrequenzmesstechnik)

A microwave equivalent circuit (2)

- For our example the noise-temperatures of the individual elements would contribute according to the fractional dissipation of some power fed from and external generator into this structure..in other words about 10% contribution from the slightly lossy waveguide (0.5 dB) and 90 % from the load at cryo temperature. Remember that the waveguide can easily be several meters long.
- Thus if the load is at 4 Kelvin the total noise – temperature of the structure (seen au the end [worst case] would be about 35 Kelvin

Discussion of limits and validity of the model

- Of course this is a VERY simple model in particular since the waveguide is considered to be monomode.
- In reality we have a HIGHLY over-moded structure (millions of modes) considering a beam-pipe with say 10 cm diameter for 10 micron wavelength.
- This is easier to handle in the ray optics approach.
- And we do not really know taking into account the surface roughness how the thermal power will be repartitioned amongst those many modes.
- In addition cooling the complete pipe would shift the max of the emission to longer wavelength, where for the new solution we would probably just lower the intensity

Next steps

- We should/could carry out some measurements on a warm waveguide section with such a cryo load inside) using a 10 micron IR camera (caution: cadmium telluride window required) and see what we can measure and compare with the simple theory.
- Maybe a simular configurations exists already in some machine and we just need to do the observation (a cryo cavity will not do as it not “black” inside)
- Many thanks to Soren P. Moller, R.Garoby and Erk Jensen for helpful comment and good discussions.

The End

- If it does not work ..lets forget it.
- If it does work , we could call it the
- Ebeltoft infrared photon trap
- Since it was invented and discussed during the Ebeltoft CAS 2010 (the cryo part would be a kind of trap for the residual photons coming from the warm but low emissivity part of the structure)