Study of Energy Transfer Mechanism for a Synchrotron X-ray Gas Absorber with COMSOL Multiphysics

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Abstract

The high power of X-ray beam delivered by synchrotrons and free electron lasers, up to 240 W/mm2, requires heat load management solutions to obtain the best performance from the optical elements which will shape the beam for its use in the experimental stations [1]. One solution is the use of gas attenuators: a tube filled with an inert gas, usually Argon or Krypton, is placed between X-ray source and the first optical element (figure 1); it will absorb the lower energy X-rays while letting pass through the high energy ones [2]. However, gas heating and ionization will increase the temperature and decrease density along the beam path, modifying the X-ray absorption from that expected from the initial conditions.

In this work we first used the CFD module together with the heat transfer module to create a 2D model of the gas cylinder including thermal conduction and free convection (figure 2). The results show that the gas movement does not play an important role on the heat transfer, and that the temperature profile does not change when we remove the gas flow. However, such a model overestimates the gas pressure and temperature, and underestimates the density and X-ray absorption along the beam path.

To take into account the diffusion and recombination of ions, electrons and excited states created by X-ray beam, we have started an exploratory work using the Plasma module, together with the Heat Transfer module. The electron reaction rates are calculated from the cross sections using the BOLSIG+ code [3]; the heavy species reactions are taken as temperature dependent [4]. According to this model, most of the input power is radiated away from the gas via atomic transitions, without heating, and only a small fraction actually heats up the gas. These results have to be verified by the experimental results, and we expect will help to operate existing gas attenuators by providing the operation conditions needed for the desired attenuation, and will allow a more efficient design of future ones by determining the optimal parameters as length, diameter and pressure of the gas.

Reference

[1] A. I. Chumakov et al., J. Synchrotron. Rad., 21 315-324 (2014)

[2] H. Requardt et al., J. Phys. Conference Series 425 022002 (2013)

[3] G. J. M Hagelaar and L. C. Pitchford, Plasma Sources Sci. Tech. 14, 722-733 (2005)

[4] George M. Petrov and Carlos M. Ferreira, arXiv:1308.2593 [physics.plasm-ph] (2013)

Figures used in the abstract

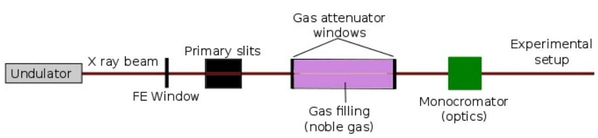

Figure 1: Standard beamline setup

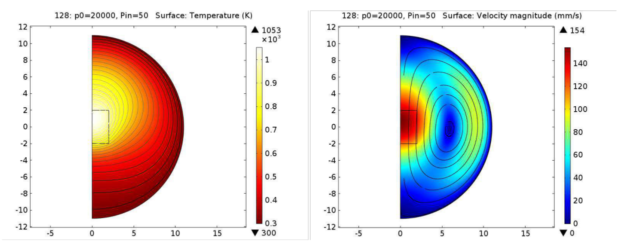

Figure 2: Temperature and velocity profiles for 200 mbar and 50 W/m.