Cryogenic cooling of monochromator crystals: Side cooling or direct cooling?

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At the ESRF, 15 Beamlines are equipped with liquid nitrogen cooled monochromators. Liquid nitrogen enables to cool the silicon crystals down to a temperature region where a/k has very low values (a= thermal expansion, k= thermal conductivity of Silicon), and, consequently to reduce the thermal deformation induced by the beam heat load. The most commonly used cooling method is to let liquid nitrogen flowing inside copper absorbers, which are clamped to the sides of the crystals. The heat flow is evacuated from the crystal though the silicon – copper interface, with possibly some intermediate material like indium or indium-gallium, intended to improve the thermal contact. In order to suppress this thermal resistance, some attempts have been made to implement direct cooling: the liquid nitrogen flows directly inside Silicon channels, which requires a vacuum tight sealing between the silicon block and the parts feeding the channels.

In a first part, calculations results will be presented, enabling to assess the gain that can be expected from direct cooling, compared to the classical side cooling technique: For a typical geometry and beam parameters, finite element calculations have been made to predict the crystal slope error as a function of the incoming power, with a good consistency with experimental data (1). These calculations have been done for various heat transfer coefficients, so that the effect of direct cooling can be predicted.

In a second part, based on a few crystals assemblies in use at the ESRF, the critical points associated with side cooled and with directly cooled crystals will be mentioned and discussed.

(1) Lin Zhang, Wah-Keat Lee, Michael Wulff, Laurent Eybert. (2003). The performance of a cryogenically cooled monochromator for an in-vacuum undulator beamline. J. Synchrotron Rad – 10, 313, 319.