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Fundamentals of heat transfer enhancement using conductive metallic porous media

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At the Advanced Photon Source, the beamline components that are subject to the very large heat load and heat flux from the x-ray beam emitted by the insertion devices make use of conductive metallic porous media to enhance convective heat transfer with water as the coolant. This technique has been applied in the design of photon shutters, fixed masks, and beamline slits. Now, the same technique is also used in optical applications with cryogenic cooling using liquid nitrogen (LN2).

While porous media, as a heat transfer enhancement technique, has been known and applied since the 1960s in high-heat-load applications, an analytical formulation and understanding of it has been lacking. The previous simplified analytical attempts have been in the areas of the application of fluid beds, one-dimensional flat channel heat transfer for geothermal simulations, and/or filtration/drying processes.

Recently, we have advanced the formulation and solution of this complex, forced convection, thermo-hydraulic problem to round flow channels both with water cooling in single phase and subcooled cryogenics (boiling with LN2) in synchrotron applications.

Fundamentals of the porous media heat transfer are explained, solutions are discussed, and comparison with the available experimental data are presented.

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