## SESSION 13: Cryocooler Analysis & Modeling Techniques

**Paper No. 13-1 Thursday Afternoon 1:45 PM**

# *Improvement of a Two-Stage 4-K Pulse Tube Cryocooler with Low Input Power and Comparison to Numerical Simulation*

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The development and optimization of a new cryocooler working at liquid helium temperature is a long and time-consuming process that can be supported and improved by using suitable numerical software. The numerical simulation software Sage is appropriate for the representation of such cryogenic systems, but difficulties in converging in the range of liquid helium temperatures are well known. Nonetheless, this work proves it to be a powerful tool for analyzing complete low temperature systems in the 4K range.

More specifically, a numerical model in Sage has been constructed, which displays a two-stage 4 K GM-type pulse tube cryocooler with a low input power of about 1 kW, where the coefficient of performance has been doubled. The cryocooler was initially designed for use with single photon detectors at 6 K and has recently been improved for the usage at 4 K. The geometry and regenerator matrix is optimized in two steps to increase the cryocooler's cooling performance. For each step a prototype was manufactured and the corresponding numerical model was calculated. The calculated cooling power is in good agreement to the experimental findings. The numerical models now give insight on the changing thermodynamic parameters due to improved geometry and regenerator matrix. The expected influences of the described optimizations are well represented by the numerical calculations and will be displayed in the presentation. Thereby, it is demonstrated, how Sage simulations allow to draw conclusions on the design and improvement of new pulse tube prototypes beforehand.