Development and test of a space-qualified Laue lens module

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Abstract

In a collaboration between the French Space Agency, Thales Alenia Space, the Institut Laue-Langevin and the Centre d’Etude Spatiale des Rayonnements, we have built and tested the prototype of a Laue lens module for nuclear astrophysics. The prototype module was designed to comply with the requirements of a space mission, while featuring a high packing ratio for its 1.5x1.5cm footprint crystals made from Copper and Silicon/Germanium. The crystal are aligned and glued individually using three accurately machined pins. We present the design, the methods used to measure the crystal alignment, and the results of the metrology before and after environmental tests. With this dedicated industrial study we validate the module’s capability of:

1) maintaining the crystals individual performance (reflectivity, mosaicity) through crystal assembly and gluing,
2) precision alignment to better than 15 arcsec,
3) conservation of the crystal performance and alignment (better than 8 arcsec) after vibrational test.

Requirements

- Accomodation of 1.5x1.5cm footprint crystals
- Materials : Cu (3 and 9mm thickness) and SiGe (23mm thickness)
- Precision of alignment : < 25arcsec after gluing and environmental tests
- Conservation of the crystals reflectivity and mosaicity
- Paking factor of 96%
- Minimal absorbing mass in optical path.

Module characterization

Verification measurements at Gams5 (Fig 3)
The alignment of the crystals, as well as their performance (reflectivity and mosaicity) are verified (Fig 4):
   - After gluing
   - After vibrational tests.

Fig 3: Gams5
Fig 4: Verification at Gams5

Assembly procedure

1) For each crystal we measure a miscut (angle between the external surface and the diffracting planes) on Gams5 at the ILL nuclear reactor (Fig 2).
2) On the prototype module, each crystal has its dedicated area consisting of 3 blocks that are machined by diamond turning, compensating the miscut of the crystals. The blocks provide an alignment to within 1arcsec of the Bragg angle.
3) The crystals are cimented on the module with an optical glue at 20°C. Only the space between the 3 blocks receives the glue – the crystal is supported by the bare blocks. Gluing takes place in a clean room.

Conclusion

Fig 5 shows the evolution (top to bottom) of the misalignment during all phases of crystals mounting, gluing and vibrational tests. The main results are:

- SiGe crystals were glued onto the prototype module with precisions better than 10arcsec (Fig 6)
- Individual crystal performances (reflectivity and mosaicity) were maintained during gluing
- The vibrational tests broadened the alignment-distribution by ±7 arcsec only w/r the position after gluing

The overall precision of the crystal alignment on our prototype lens module is 9±6arcsec for SiGe crystals, and 37.6±7 arcsec for Cu crystals.

Fig 5: evolution of crystal misalignment

Error after diamond turning (optical check)
Measure after gluing (gamma ray beam)
Measure after vibratible (gamma ray beam)
Measure after thermal cycling (gamma ray beam)

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