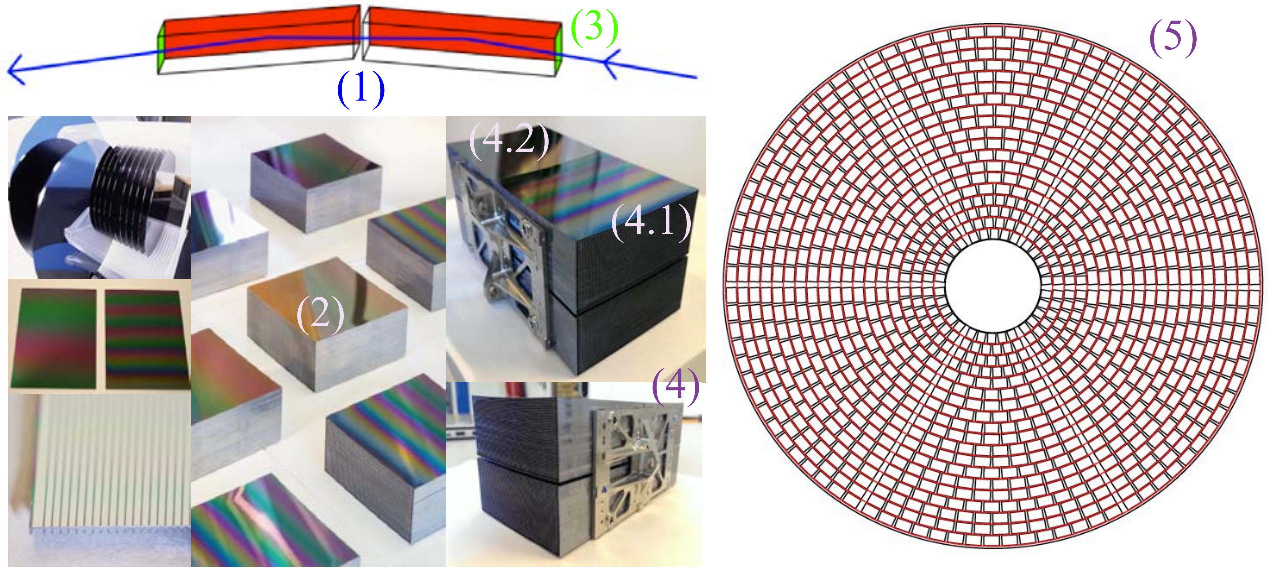
THE ATHENA X-RAY TELESCOPE MIRROR BY NUMBERS

by R. Willingale, Dept. of Physics and Astronomy, University of Leicester (United Kingdom)

The Athena Mission will incorporate the largest X-ray primary mirror ever built, with an aperture diameter of 3 m, a mirror component mass of ~300 kg and total mass including support structure of ~650 kg. The Wolter I grazing incidence (1) reflection geometry is used to produce a true image of the X-ray sky in the energy band 0.1-15 keV. The effective area at 1 keV is 2 m^2, a factor of ~14 larger than the largest extant Wolter I mirror modules used on ESA's XMM-Newton X-ray space observatory. The angular resolution is 5 arc seconds (Half Energy Width), a factor of ~3 better than XMM, over a field of view of 40 arc minutes in diameter. This impressive performance is made possible by an innovative new X-ray technology, Silicon Pore Optics (SPO).

The SPO mirrors are made using commercially available 12-inch Si wafers. The wafers are diced and grooved to produce Si mirror plates, each typically 100x40 mm^2. 35 plates are accurately cold-welded together to form stacks (2) with an aperture split into ~1500 rectangular pores where each pore (3) has an aperture 0.605x2.3 mm^2.



Left: the production of a Mirror Module: ribbed wafers are stacked in an SPO module and 4 are combined in two pairs to form a Mirror Module. Right: front view of the Mirror Assembly Module showing the > 1000 MM required to reach the 2m^2 effective area at 1 keV.
Credit: R. Willingale and ACO Team

Two stacks are precisely aligned to produce an X-ray optical unit (XOU) which behaves as an X-ray lens-let. X-rays are focused by 2 grazing incidence reflections (1), 1 in the front stack (4.1) and 1 in the rear stack (4.2). Two XOUs are integrated together to produce an Athena Mirror Module (MM) (4) and finally, ~1100 MMs are mounted and co-aligned to populate the mirror aperture (5). A total of ~150,000 Si plates are required to construct the full mirror. The area of super-polished X-ray mirror reflecting surface is 400 m^2, sufficient to completely cover 2 tennis courts. Because of the SPO construction the aperture is divided into ~2.6 million pores.

Production of the mirror is a formidable task of optical engineering. The SPO stacks are to be made by a fully automated robotic process and 3 assembly robots working for 3 years will be required to produce the full complement of MMs. The stacks in the MM are aligned using an X-ray synchrotron beam. All individual MMs must be tested and calibrated in X-rays to measure the point response function and collecting area as a function of X-ray energy. The fully integrated mirror must also be tested and calibrated on the ground using a long X-ray beam facility with length greater than 500 m, a beam diameter of at least 3 m and a vacuum tank large enough to accommodate the mirror and an X-ray imaging detector at the focal distance of 12 m.