About ten years ago University of Melbourne researchers (Wilkins et al.1989) described the principles of round-pore microchannel plates working as X-ray focusing elements. By making square-shaped pores they predicted that the focusing efficiency is improved, albeit with a cross-shaped focus. This was first experimentally demonstrated with real MCPs by Leicester University (Brunton et al. 1993). Through a recently finalised ESA (European Space Agency) development programme, with Leicester Space Research Centre as adviser, Photonis has developed square-pore, radially-packed MPOs. Slumping two such plates to different radii and combining them into a pair forms a so called Wolter optic. For the first-time-ever, these prototype optics have produced an X-ray point focus - a revolutionary achievement - that will open a new window on how to build light-weight X-ray space telescopes. Two space science proposals, LOBSTER, to fly on the ISS in 2009, will use square-pore, square-packed MPOs and the HERMES experiment for BepiColombo intends to use square-pore, radially-packed MPOs. MPOs can focus X-rays up to 60 keV, are low-cost devices compared to capillary focusing elements and may find new applications in constructing intensified X-ray sources etc.. Photonis welcomes you to co-develop the technology further.
CHANDRA
(AXAF)
This technique works well, although it's rather inefficient, because the mirrors are used almost edgeways-on. X-ray telescopes of this type consist of a "nest" of many such mirrors - it's the only way of collecting sufficient light from faint, distant astronomical objects.
Mirror elements are 0.8 m long and from 0.6 m to 1.2 m diameter.
LIFE THROUGH THE EYES OF A LOBSTER

The eyes of a Lobster work by *reflection*, rather than the principle of *refraction* which our own eyes and those of most other animals and birds, use. The figure below shows the eye of a Lobster, viewed with a powerful microscope.

Left: The eye of a lobster, viewed with a microscope. Right: closeup of a small area of the eye. The eye consists of millions of square “channels”; each channel measures approximately 20 microns (or two hundredths of a millimetre) across..
Focusing action of an unbent one-dimensional MCP showing sharp focusing action for rays incident on a given channel of a MCP at same x coordinate and also showing \( f_r = l_s \).

For rays incident on a given channel of a MCP at different x-coordinate values there is a focusing error which has a maximum value of \( 2t \).

Fraser et al.
Leicester Space Research Centre

ESA CONTRACT
Schematic illustration of focusing action of a MCP with bending radius chosen so as to produce quasiparallel beam from a point source.
Schematic illustration of effect of uniformly bending a MCP on its focusing action and in particular, showing that $l_F$ no longer equals $l_S$.

Focusing and collimation
Fabrication stages of a micropore optic

Channel cladding → Soluble core → Assembled preform → Stack

2nd draw stack → Square block

2nd draw MF → Stack

Fuse and slice → Radial block

Grind and polish → Etch and process → Slump

Fig. 1
Figure 8 - 10 μm square-pores in a square packing arrangement
3.5 Arc min FWHM
1.7 keV S, K X-rays
Figure 5 - Square-pore, radially-packed multifibre configuration

Figure 6 - Wolter type 1 micropore optics configuration
Figure 10 - Radial stacked multifibre configuration (example)
Figure 9 - 10 μm square-pore, radially-packed plates (unetched): top) sample plate with a central solid core, bottom) sample plate without central solid core
Figure 10 - Curvature profiles of the 2nd pair of Wolter MPOs
Figure 12 - Focused image of a 10 keV X-ray source produced by a 50 mm diameter radially-packed micropore optic
OUTLOOK

- We have to repeat, in details, the whole process (NEW ESA CONTRACT)
  Square-pore, radially-packed, curved (BepiColombo, XEUS)

- Work on LOBSTER
  Square-pore, square-packed, curved MPO

- Possible medical and lithography X-ray applications

- Neutron optics?

- Study Si MPO for X-ray focusing
REFERENCES

1. NIM-A in print:

**X-ray focusing with Wolter microchannel plate optics**
G.J. Price\textsuperscript{a}, A.N. Brunton\textsuperscript{a}, M.W. Beijersbergen\textsuperscript{b}, G.W. Fraser\textsuperscript{a}, M. Bavadaz\textsuperscript{c}, J.-P. Boutot\textsuperscript{d}, R. Fairbend\textsuperscript{d}, S-O. Flyckt\textsuperscript{d}, A. Peacock\textsuperscript{c}, E. Tomaselli\textsuperscript{c}

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\textsuperscript{d} Photonis SAS, Avenue Roger Roncier, B.P. 520, F-19106 Brive, France

2. NIM-A in print

**Hard X-ray imaging with microchannel plate optics**
G.J. Price\textsuperscript{a}, A.N. Brunton\textsuperscript{a}, M.W. Beijersbergen\textsuperscript{b}, G.W. Fraser\textsuperscript{a}, M. Bavadaz\textsuperscript{c}, J.-P. Boutot\textsuperscript{d}, R. Fairbend\textsuperscript{d}, S-O. Flyckt\textsuperscript{d}, A. Peacock\textsuperscript{c}, E. Tomaselli\textsuperscript{c}

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3. References in 1 and 2.

4. http://www.src.le.ac.uk/lobster