Polycapillary optics for X-rays focusing: PolyCAD simulation approach and first results

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Introduction

X-ray System Optics

- Zone Plate
- Goebel Mirror
- Kumakhov Lens
- Diffractive Optics

X-ray Microscopy

Multi-Layer Structures
Parallel Beam

X-ray Diffractometry

XRD - XRF - μXRD - μXRF

Medicine - Biology - Astrophysics - Archeology
System Geometry

• Total External Reflection inside a Cylindrical, Conical or Bending channel

• Initial Conditions
  i) Starting Point -> Source
  ii) Entering Point -> $P_0$
  iii) Entering Direction -> $\vec{v}_0$

• Channel Surface Equation
Results

We show the following simulation configurations:

- Polycapillary Semi-Lens:
  - from **Divergent** to **Parallel** mode;
  - from **Parallel** to Convergent mode;
- Cylindrical Polycapillary Optics with a **3D-like** Source;
- **Full-Lens** Polycapillary Optics.
Semi-Lens Optics (I)

- Divergent to Parallel Mode
- $E = 1$ keV
- $R_G = 1$ cm, $R_M = 0.8$ cm, $\rho = 0.9 \times 10^{-3}$ cm, $L = 5$ cm,
Semi-Lens Optics (II)

- Parallel To Convergent Mode
- $E = 1$ and $8 \text{ keV}$

- Gain Factor (photons/area) respect to the impinging parallel beam:
  - $17$ (1 keV)
  - $14$ (8 keV)
3D Source

- Reconstruction of the 3D intensity distributions beyond a **cylindrical polycapillary** due to a couple of X-ray spherical source

- The main peaks are located at the coniugate points respect to each sphere position
Focusing Effects

- **Full-Lens** Polycapillary Optics
- \( E = 1 \) keV
- Source in the **optimal** position: ~9 cm from the outlet plane
- Source **far** from the optimal position (~5 cm)
- Double peak focus structure: analog to **Intrafocal** and **Extrafocal Effect** (as Airy Disk for an optical telescope)
Comparison with Experiment

- Simulation of an Experiment at BESSY to focalize Synchrotron Radiation (E~8 keV), with a polycapillary semi-lens (Shcherbinin et al., 2002)
- Same spot dimension (the radius is about 0.4 mm)
- Similar Transmission Coefficient (Simulation - 34%; Experimental - 39%)
- Little difference on focal spot distance (Sim. - 6 cm; Experimental - 7.4 cm)
Conclusions

- we have shown simulation for various source-optics configurations:
  - semi-lens in parallel and convergent mode
  - cylindrical polycapillary with a 3D-like source
  - full-lens
- we have shown the behaviour of the density distribution for a polycapillary in three dimensions, in the x-y-Int. and x-z-Int. system reference
- we reconstructed as a three dimensional object the density distributions for the two spherical sources

To summarize: the software simulations obtained with PolyCAD are able to reproduce any experimental data.

As a consequence: PolyCAD may be used to:

1. design polycapillary lenses;
2. develop polycapillary system;
3. compare experimental results with theoretical evaluations
for future...

- work is in progress to test any polycapillary optical shape

- we wish to include wave theory of X-ray propagation inside capillary channels

- we wish to extend PolyCAD including X-ray channeling along curved surface, than going down to channeling in nanostructures