EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office via the User Portal:
https://wwws.esrf.fr/misapps/SMISWebClient/protected/welcome.do

Deadlines for submission of Experimental Reports

Experimental reports must be submitted within the period of 3 months after the end of the experiment.

Experiment Report supporting a new proposal ("relevant report")

If you are submitting a proposal for a new project, or to continue a project for which you have previously been allocated beam time, you must submit a report on each of your previous measurement(s):

- even on those carried out close to the proposal submission deadline (it can be a *"preliminary report")*,
- even for experiments whose scientific area is different form the scientific area of the new proposal,
- carried out on CRG beamlines.

You must then register the report(s) as "relevant report(s)" in the new application form for beam time.

Deadlines for submitting a report supporting a new proposal

- 1st March Proposal Round - **5th March**
- 10th September Proposal Round - **13th September**

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report in English.
- include the experiment number to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Submicron X-ray focusing by single-bounce ellipsoidal capillary combined with parabolic axicon lenses	**Experiment number**: MI-1381
Beamline:	**Date of experiment**: from: 31 Jan 2022 to: 04 Feb 2022	**Date of report**: 01 Mar 2022
Shifts:	**Local contact(s)**: Carsten Detlefs (email: detlefs@esrf.fr) ID06	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Dr Dmitrii Zverev (Immanuel Kant Baltic Federal University)

Dr Irina Sniguirev (ESRF)

Dr Anatoly Sniguirev (Immanuel Kant Baltic Federal University)

Report:

We implemented submicron X-ray focusing (down to several hundred nanometers) using a single-bounce ellipsoidal capillary illuminated by a ring-shaped beam produced by parabolic axicon based optical system. The optical properties of the submicron X-ray focusing technique have been studied experimentally at the ID06 ESRF beamline et the X-ray energy of 12.4 keV.

Used single-bounce ellipsoidal capillary represents a micromirror with the minor axis equal to 50 μm and major axes of 95 mm. The ellipsoidal capillary has an entrance diameter of 50 μm, and an output diameter of 8 μm providing a working distance of about 1 mm. The capillary was placed on the stage with all necessary translations and rotations at 54 m distance from the source.

First, we used the compound refractive lenses (CRL consist of Al lenses with *R* of 50 μm) with focal distance of about 1 m to focus X-rays at the first ellipse focus. In this case, only a small edge area of the inner surface of the capillary close to its exit was illuminated. The reduced image of the focal spot was observed at the second focus. However, the scattering at the edge of the capillary bore resulted in a broadening of the focal spot. Besides, a direct beam from the first focus passing through the capillary opening without being reflected increased the background.

To eliminate the influence of the direct beam background and scattering at the edge of the capillary bore, we used an off-axis ring-type illumination. Such a special form of the beam was generated by axicon based optical system consisted of parabolic axicon lenses and traditional parabolic focusing lenses. This made it possible to flexibly adjust the size of the focused ring-shaped beam produced by axicons changing the number of the parabolic lenses in the optical system. It was shown that the diameter of the annular beam decreased with the increase in the number of lenses. The combination of 3 axicons with 5 aluminum parabolic lenses made it possible to achieve an acceptable size of a focused annular beam of about 11 μm (diameter). In this case, it was the annular section of the capillary surface that reflected X-rays to the second focus.

The test of the elliptical capillary has resulted in focusing about 2 μm FWHM for a flat parallel beam, about 1 μm FWHM for combined capillary with the CRL focused at the first ellipse focus. We were able to obtain focusing about 500 nm FWHM, taking advantage of the ring-shaped beam generated by the axicon based optical system. Due to the annular illumination of the capillary surface the influence of the scattering at the edge of the capillary bore was excluded. The overall gain of the two-step focusing system was three orders higher compared with a flat monochromatic beam. Applying the axicon based optical system, a flux enhancement by almost a factor of three in comparison with the CRL focused at the first ellipse focus was measured.