New Optical Systems

Overview of the systems we have proposed

Stará Lesná 2007.

Chadzitaskos G.

Department of Physics, FNSPE, Czech Technical University in Prague

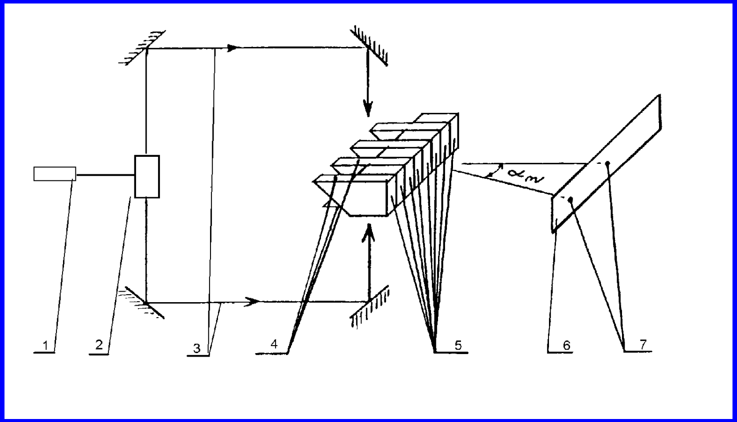
Based on

- CZ Patents:
  The two-diffraction system, Telescopical system, Telescopical system, Optical element for roetngen microscopy.
- Chadzitaskos G, Tolar J
  The two-diffraction system
  OPTICS COMMUNICATIONS 187 (4-6): 359-362 JAN 15 2001
- Chadzitaskos, G. - Tolar, J.
  Telescopic system with a rotating objective element
  Washington: The International Society for Optical Engineering, 2004. 5 s. ISBN 0-8194-5419-2.

The two-diffraction system

Beam splitter with gratings

- Two slits two gratings: Distinguish between channels different diffraction patern
- Distinguish $\gamma = 1$
- Not distinguish $\gamma = 2$



$$\sin \alpha_n = \frac{n\lambda}{2d},$$

$$\sin \alpha_n = \frac{n\lambda}{d},$$

Intensities

- n slits, width a, spacing $a + b$

$$I_\gamma(\alpha) = I_{\gamma 0}\left(\frac{\sin(\frac{\pi a}{\lambda}\sin\alpha)}{\frac{\pi a}{\lambda}\sin\alpha}\frac{\sin(\frac{n\pi\gamma(a+b)}{\lambda}\sin\alpha)}{\sin(\frac{\pi\gamma(a+b)}{\lambda}\sin\alpha)}\right)^2$$

- p percent of photon is of case $\gamma = 1$

$$I_3(\alpha) = \frac{p}{100}I_0\left(\frac{\sin(\frac{\pi a}{\lambda}\sin\alpha)}{\frac{\pi a}{\lambda}\sin\alpha}\frac{\sin(\frac{n\pi(a+b)}{\lambda}\sin\alpha)}{\sin(\frac{\pi(a+b)}{\lambda}\sin\alpha)}\right)^2 + \\ + \frac{100-p}{100}I_0\left(\frac{\sin(\frac{\pi a}{\lambda}\sin\alpha)}{\frac{\pi a}{\lambda}\sin\alpha}\frac{\sin(\frac{n\pi 2(a+b)}{\lambda}\sin\alpha)}{\sin(\frac{\pi 2(a+b)}{\lambda}\sin\alpha)}\right)^2,$$

Exploitation

- The 2--diffraction grating is advantageous in experiments with two--photon entangled photon states. Instead of picosecond coincidence measurements with two detectors in two channels in quantum optic experiments, we can use the two inputs in 2--diffraction grating and measure interference maxima.
- This can distinguish if both photons passed through one channel or through both channels, and if they are entangled.

Telescopic system with rotating objective element

One can use rotating objective and mathematics of tomography to reconstruct the image of the object

The angular resolution of used telescopes is almost the same in all lateral directions. For the aperture of the diameter D, light of wavelength λ, the angular resolution δ is

$$\delta \approx \mathbf{1{,}22\ \lambda / D.}$$

The area of objective is **$P = \pi D^2/4$.** In order to improve the ratio resolution area for objects which emit or reflect detectable amount of light.

New approach

For reflectors the new objective element has the form of a parabolic strip. The instrument for digitalization of images has to be located in the image plane of the telescope. It detects na integral intensity in one direction and the angular resolution in other direction is done by the dimension of objective. The angular $\boldsymbol{\delta \approx \lambda / L = B\lambda / P}$ in the direction of <u>L</u> and $\boldsymbol{\delta' \approx \lambda / B = L\lambda / P}$ in the direction of <u>B</u>.

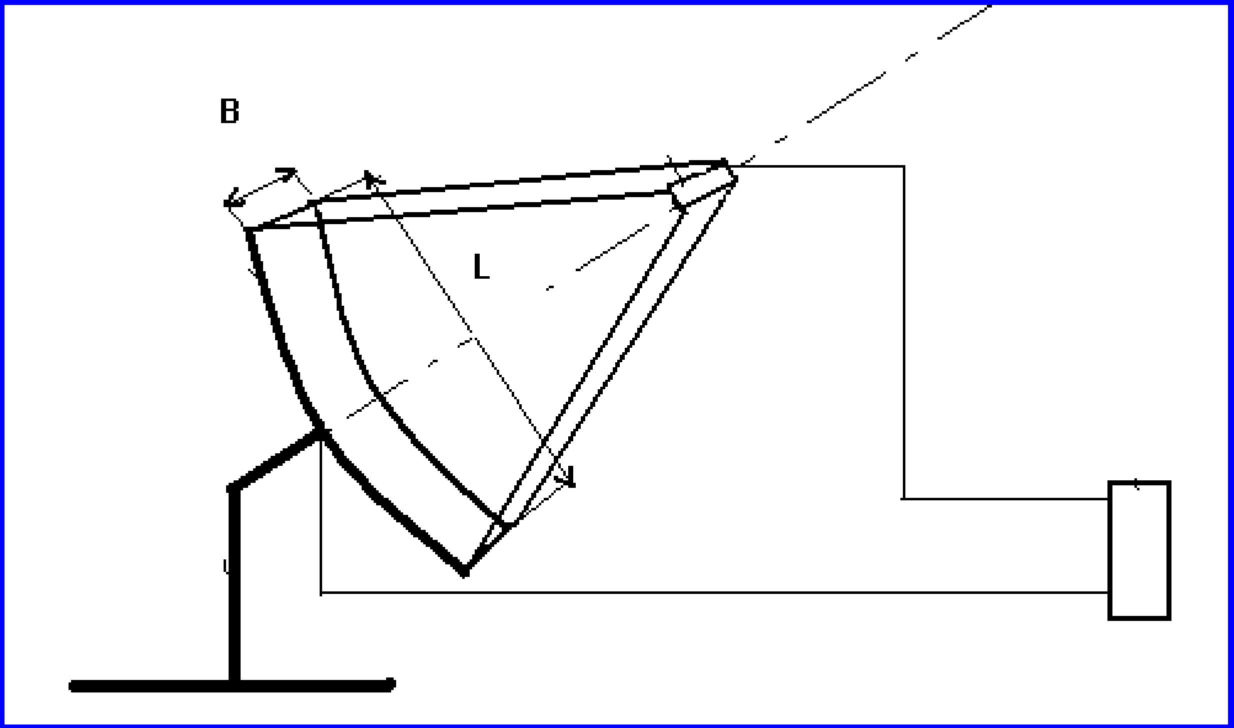
The ratio δ'/δ determines the number of images in order to reconstruct the image with maximal resolution

$$\boldsymbol{\delta \approx \lambda / L}.$$

Reconstruction - numerical solution of a system of linear equations defined by each snap. Each cell of a CCD detects integral intensity of light coming from a rectangular part of a source with.

Using the mathematics of tomography can improve the

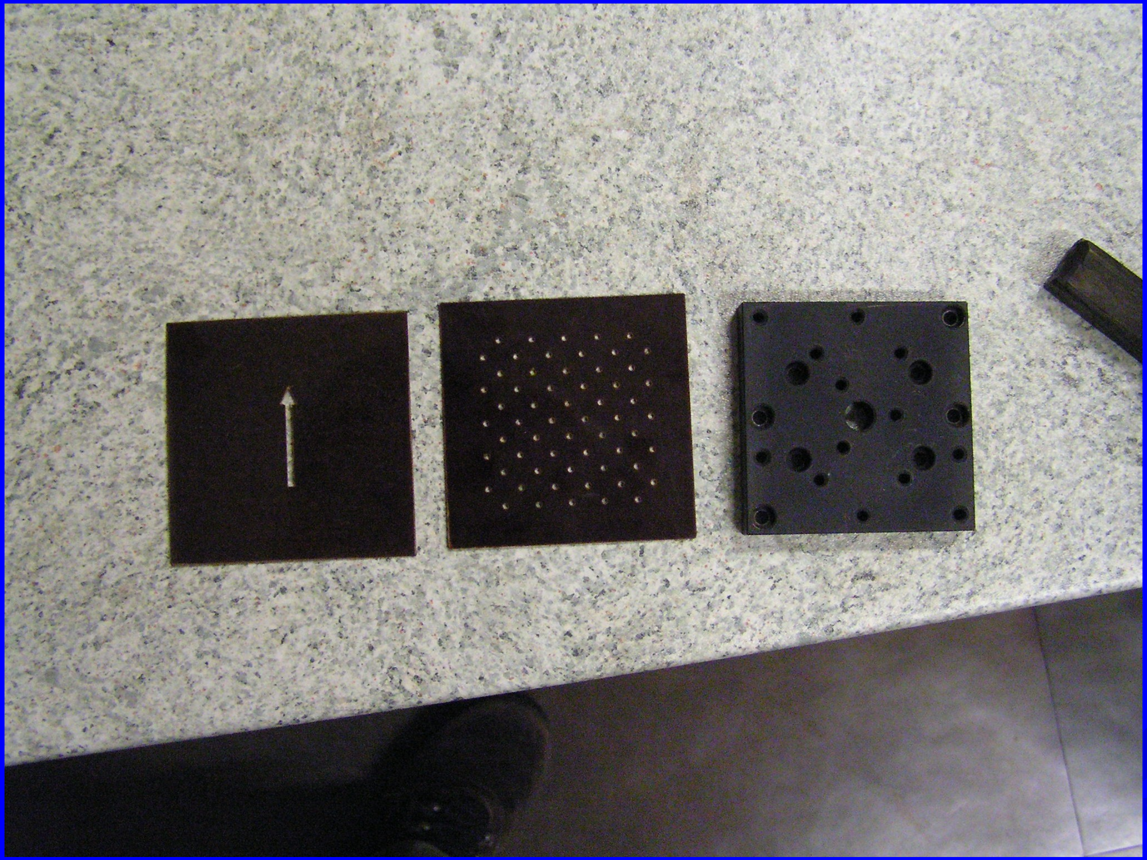
EXAMPLE



Rotating reflector with CCD

Experimental Plexiglas telescope objectives

artificial constellations for an experiment



Angular resolution

$\boldsymbol{\delta \approx \lambda / L = B\lambda / P}$ in the direction of $\underline{L}$ and $\boldsymbol{\delta' \approx \lambda / B = L\lambda / P}$ in the direction of $\underline{B}$.

The ratio δ'/δ determines the number of images in order to reconstruct the image with maximal resolution

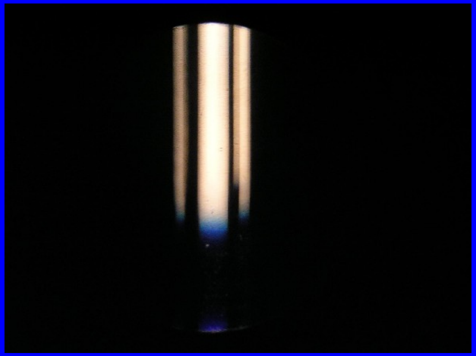
$$\boldsymbol{\delta \approx \lambda / L}.$$

Reconstruction - numerical solution of a system of linear equations defined by each snap. Each cell of a CCD detects integral intensity of light coming from a part of a source.

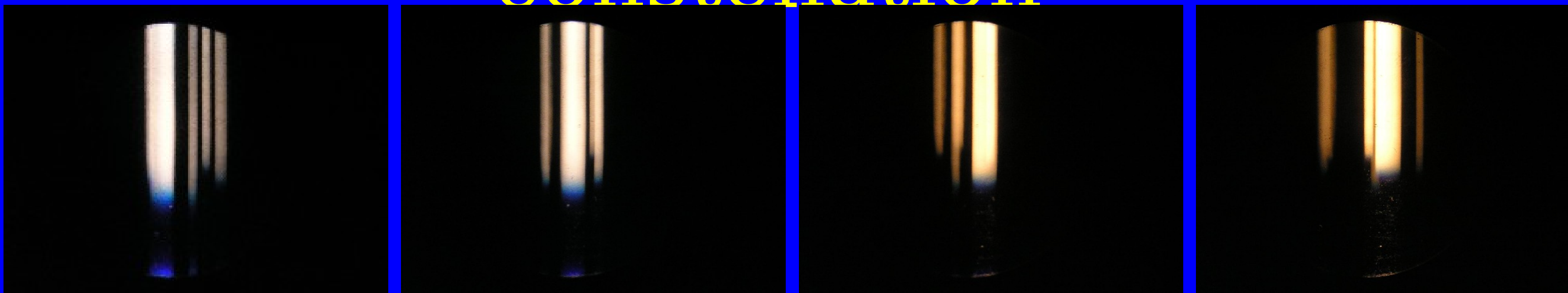
Using the mathematics of tomography can improve the resolution and the image.

Image procesing

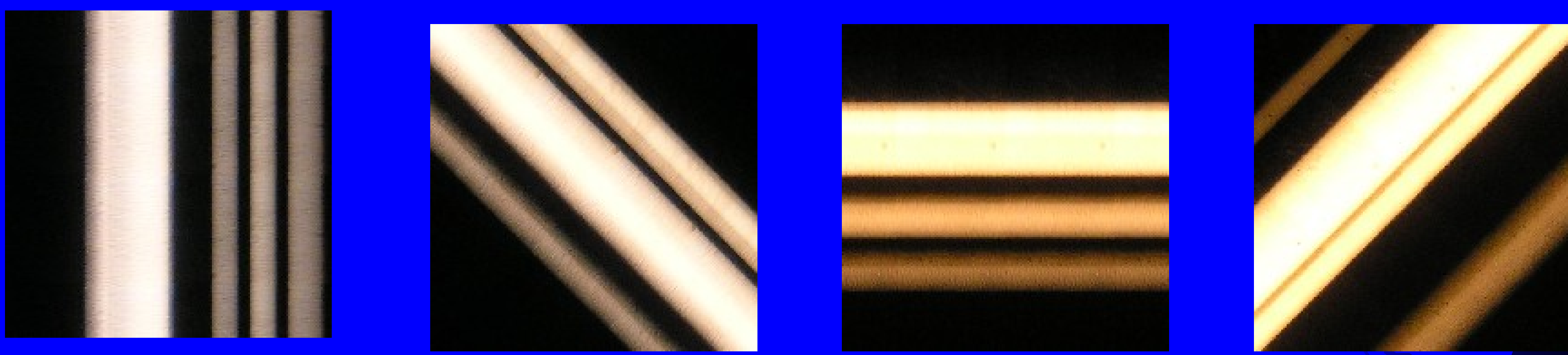
- From camera RGB uint8
- Select central part, make matrices 600 x 600x 3 and rotate, single precision
- 12th root of real matrices
- Point multiplication of 0 and 90 degree matrices
- Point multiplication, optimalization



Images of artificial star constellation



Original images at 0, 45, 90, and 135 degree



After MATLAB calculation

Image procesing

Exploitation

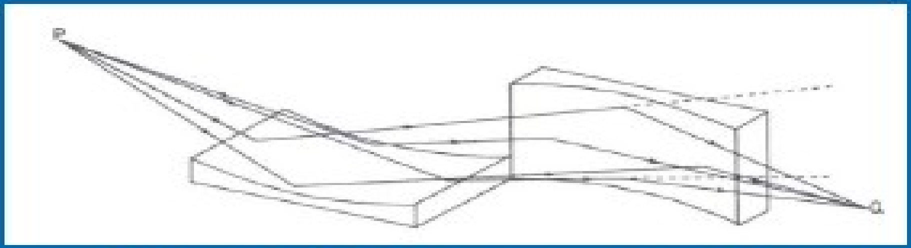
- observations of objects on the Earth from satellites,
- observations of celestial objects from satellites
- Telescopes with good angular resolution

Optical elements for roetngen microscopy.

Small wavelength

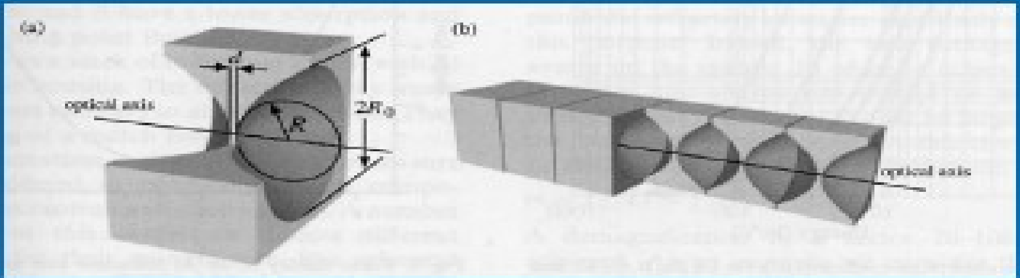
0.1 nm ≤ λ ≤ 5 nm, (14 keV – 250 eV)

⇒ better resolution than with classical light microscopy



Two-mirror Kirkpatrick-Baez grazing incidence system

Disadvantage: Magnification different in the two directions (anamorhotism)

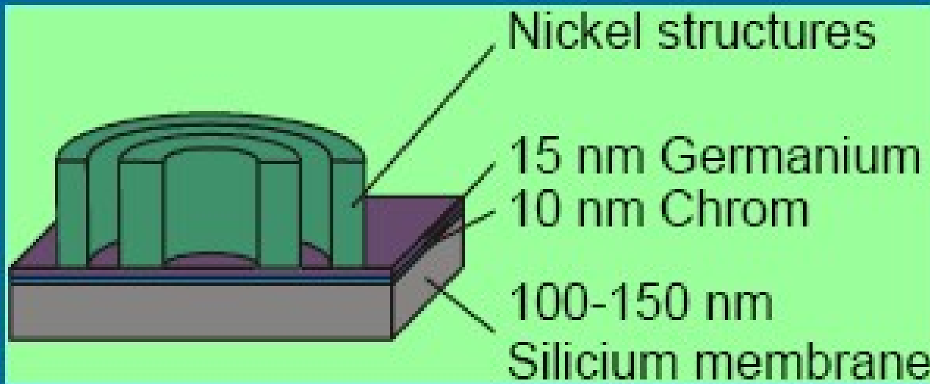


a) Individual biconcave refractive X-ray lens with parabolic profile

b) Stack of lenses forming a compound refractive lens

B.Lengeler et al., Nuclear Instruments and Methods in Physics Research A 467-468, 944-950 (2001)

Nickel zone plates for 0.52 keV



measured first order diffraction efficiency @ 0.52 keV:

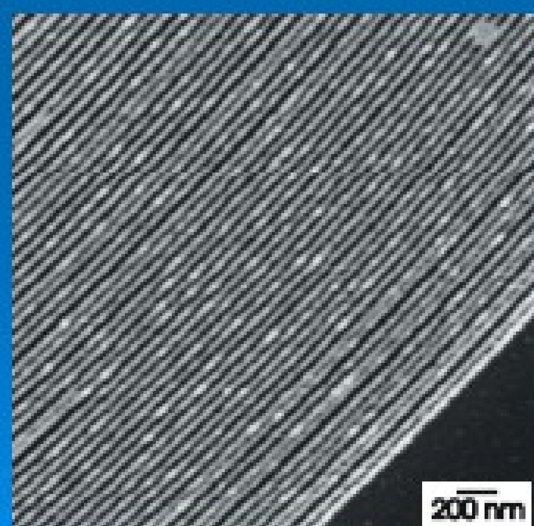
I) 10 % for dr_n = 25 nm

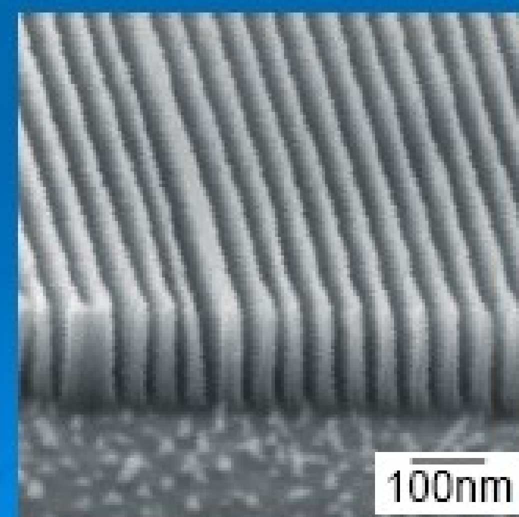
II) 15% for dr_n = 30 nm

III) 20% for dr_n = 40 nm

22 nm zone width

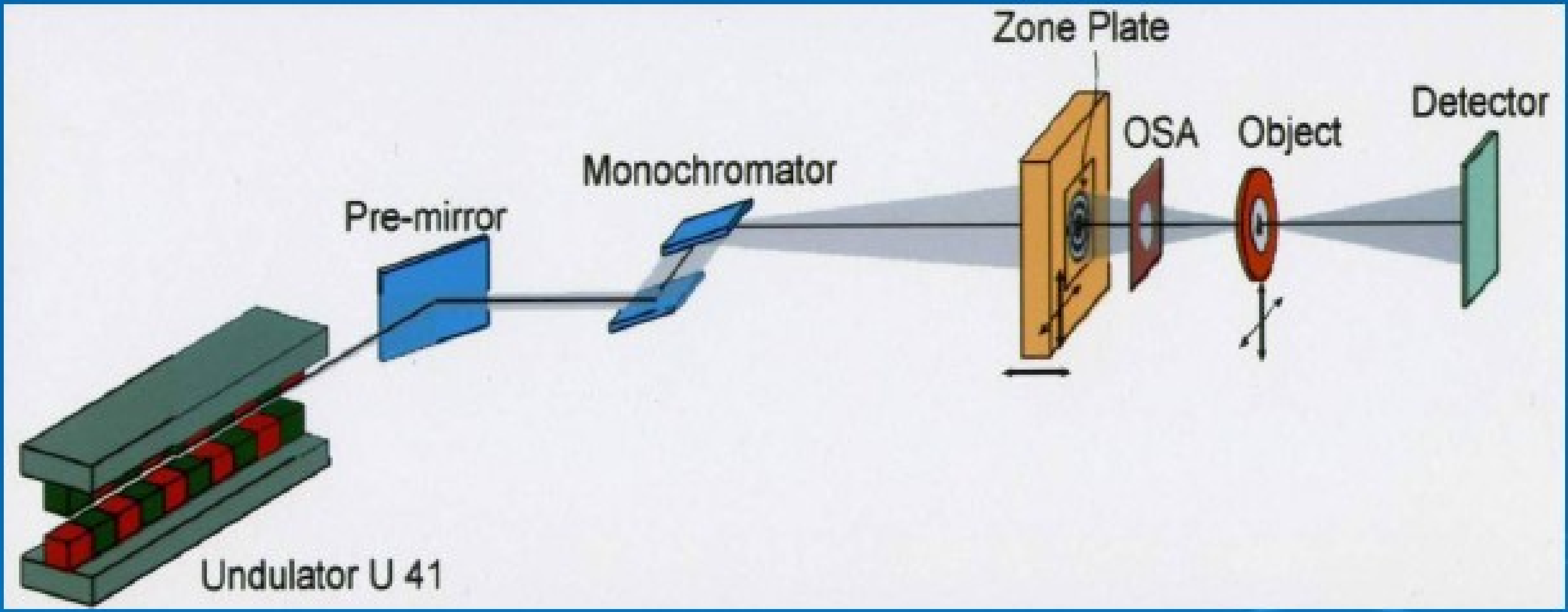
22nm line width
175nm MPEDVB
aspect-ratio 8:1





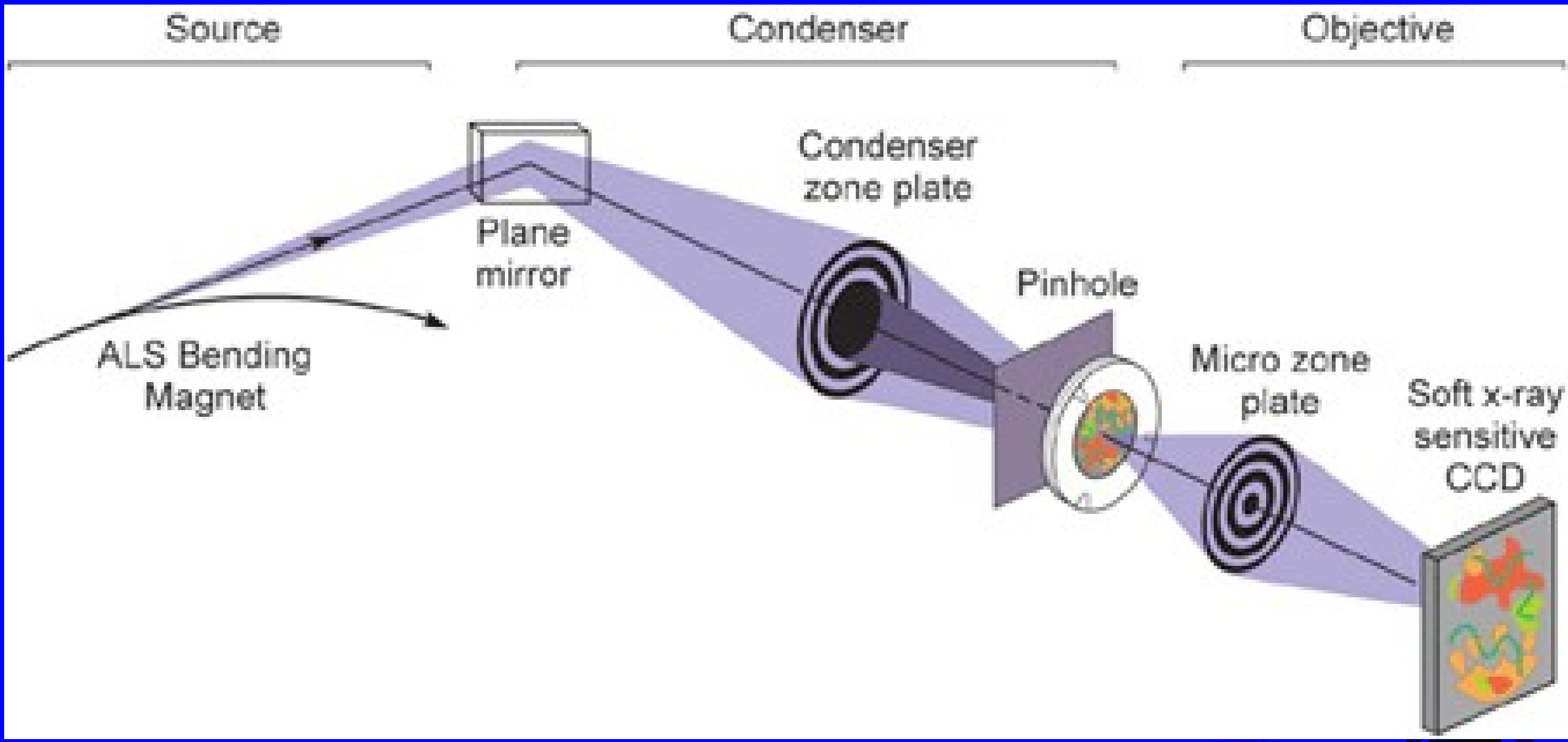
M. Peuker, Dissertation, Uni Goettingen 2000 ; M.Peuker, High-efficiency nickel phase zone plates with 20 nm minimum outermost zone width, Applied Physics Letters Vol. 78,15, 2208-2210 (2001).

Scanning X-ray microscope at the undulator U 41 BESSY II

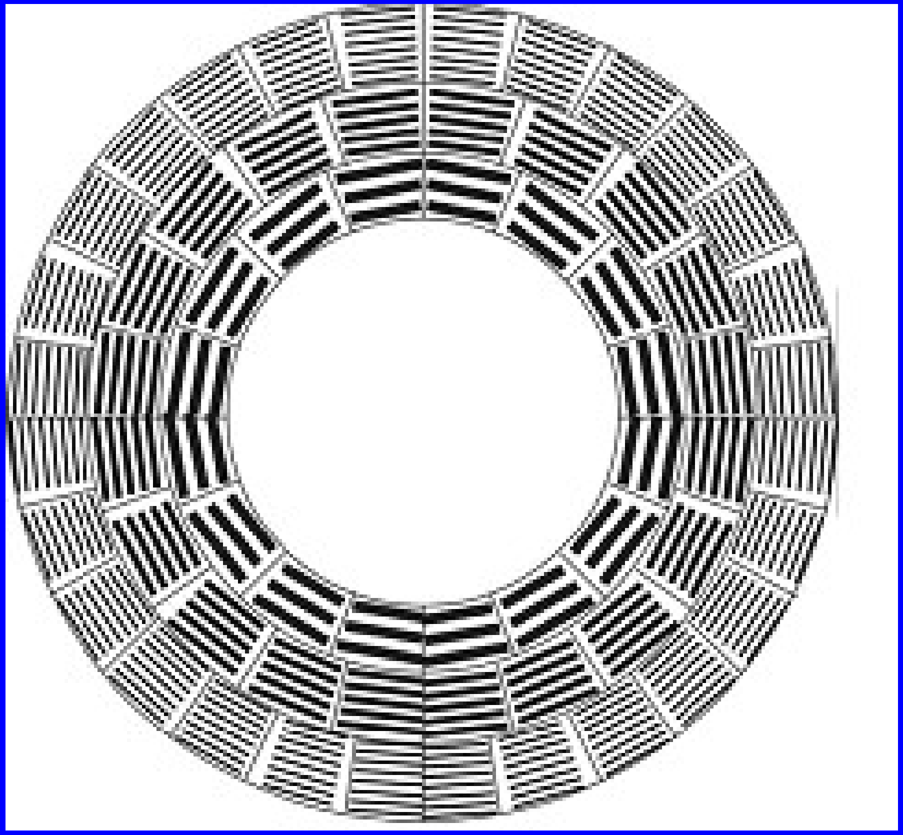


160 – 600 eV soft X-rays

U.Wiesemann, Dissertation, University of Göttingen, 2003


Source
Condenser
Objective
Plane
mirror
Condenser
zone plate
Pinhole
Micro zone
plate
Soft x-ray
sensitive
CCD
ALS Bending
Magnet

Example of zonal plate

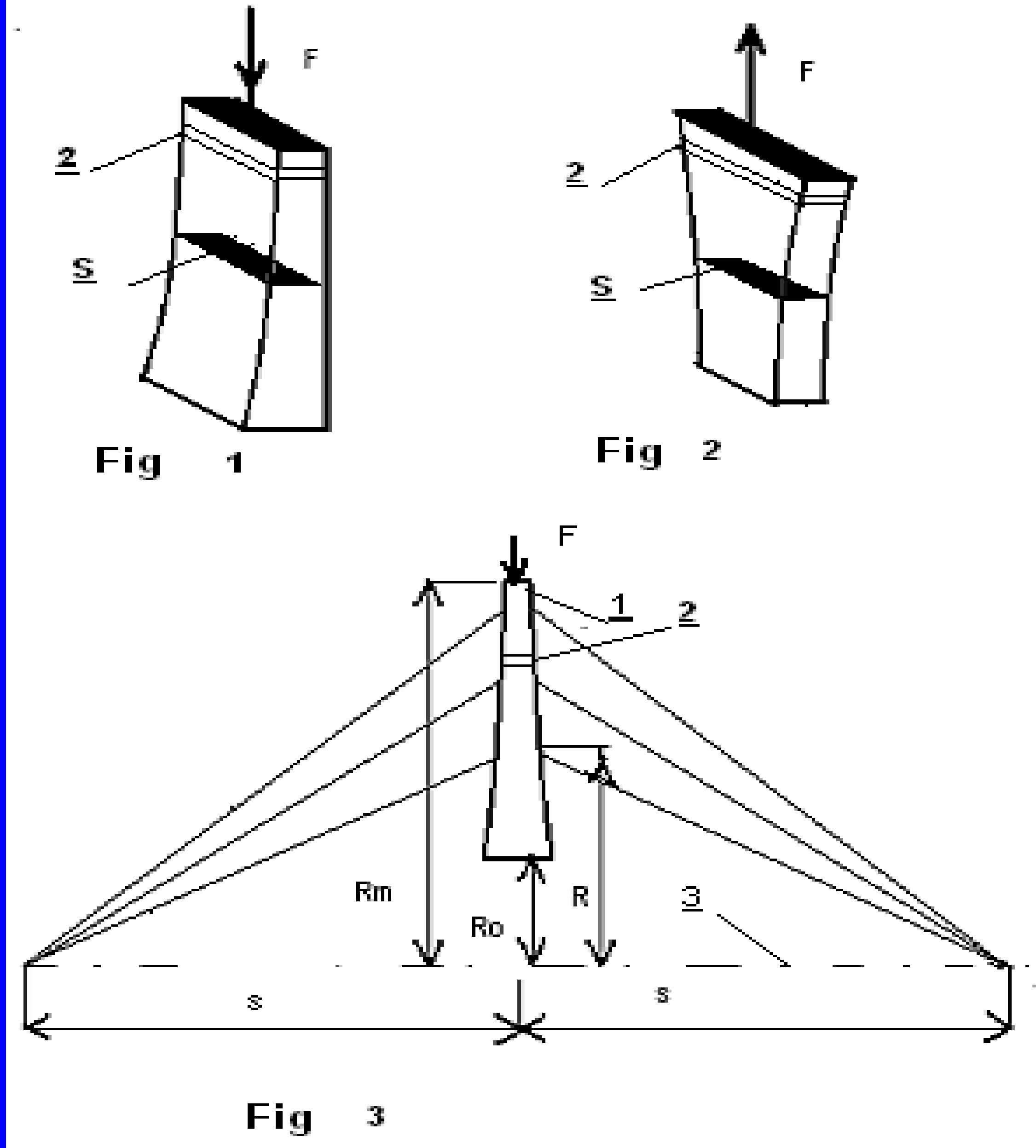


Our approach

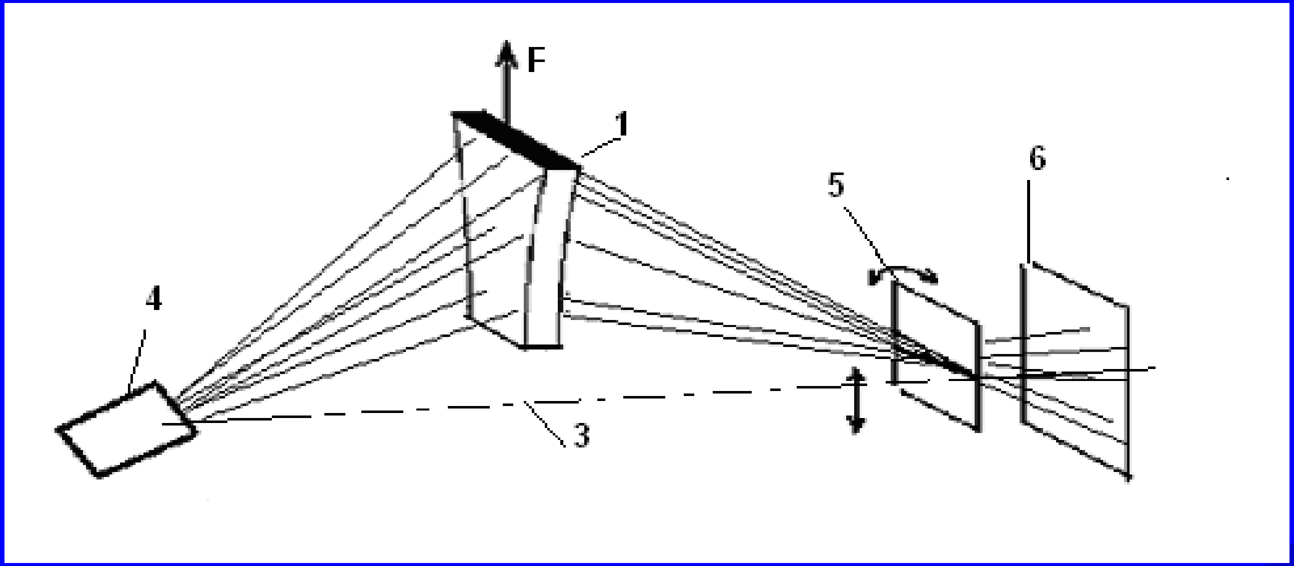
- Monocrystal under compression or tension with changing profile according the Bragg condition and the Hook law.

$$S = \pm \frac{F}{E}\left(\frac{1}{\frac{n\lambda}{2Rd_0}\sqrt{R^2+s^2}-1}\right)$$

$$F = \pm S_0 E\left(\frac{n\lambda}{2R_0 d_0}\sqrt{R_0^2+s^2}-1\right)$$

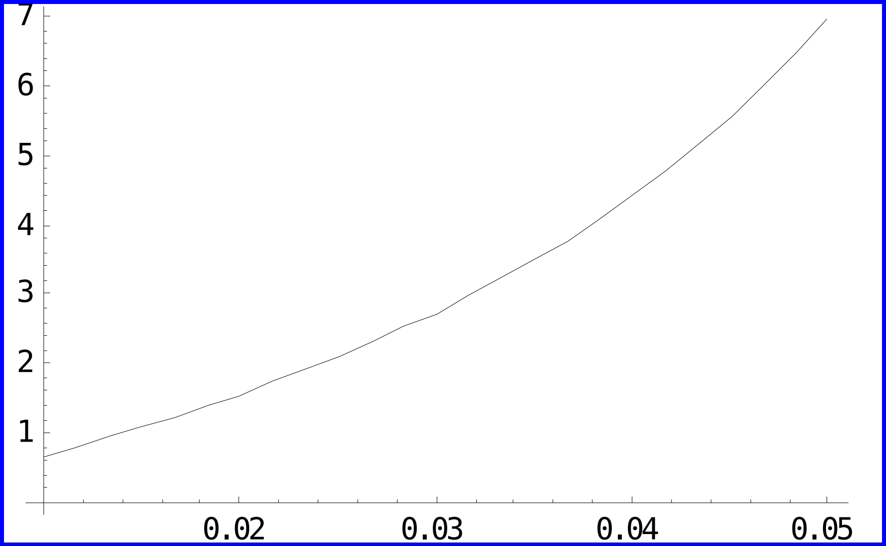


Rotational Scanning X-ray Microscope



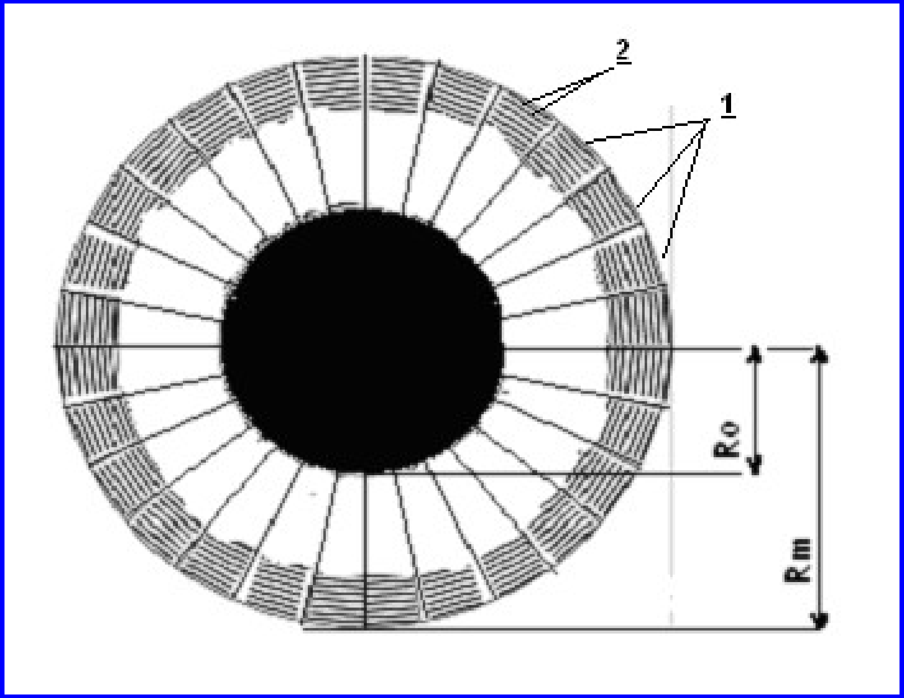
λ = 0.1 nm, do = 0.4 nm, R0 = 0.01 m , s = 0.5 m , n = 1, Rmax = 0:07 m.

S/ So



R (m)

Realization of the zonal plate from segments



Thank you for the attention