Design and focused proton beam fabrication of transmission optical gratings of quasi-sinusoidal profile in glass

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Previously:

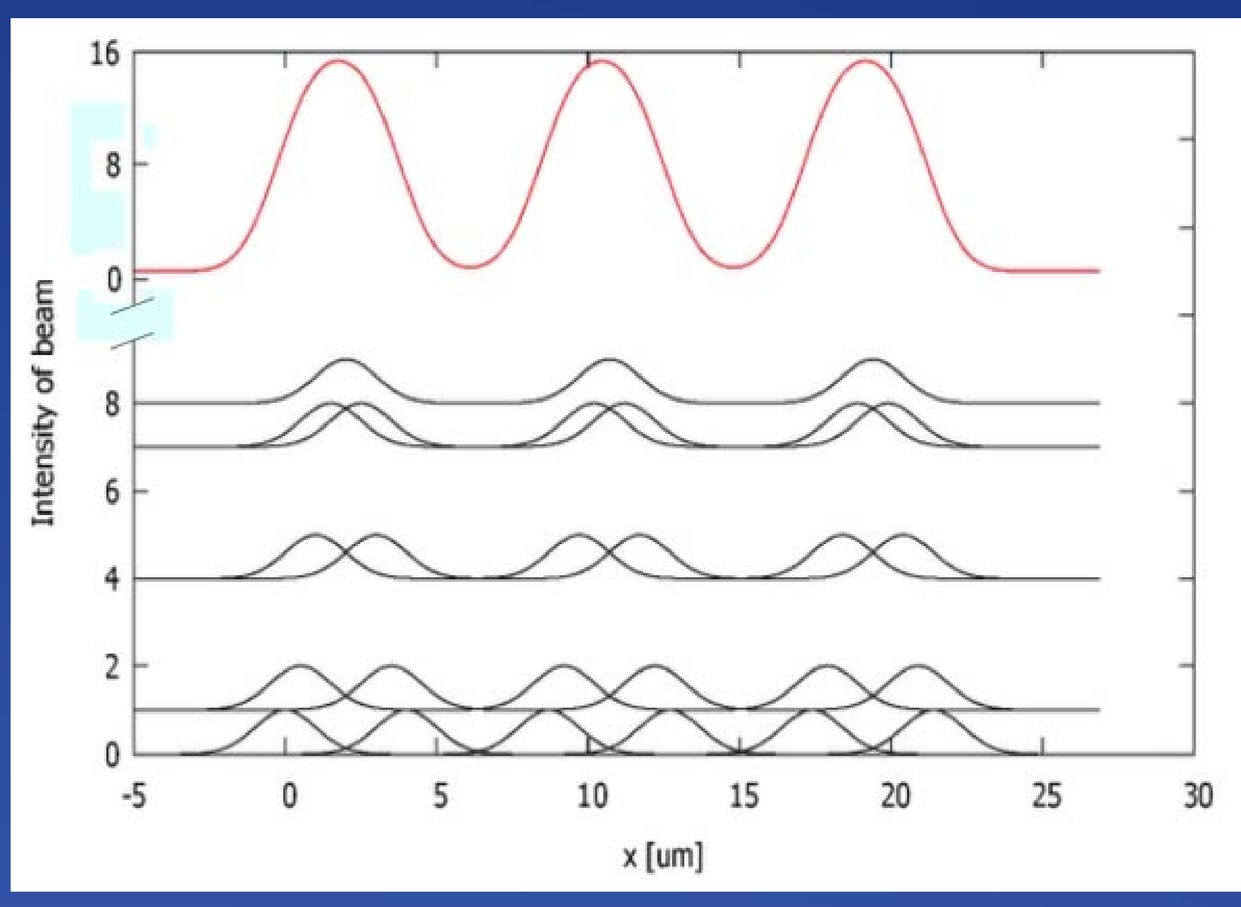
Fine transmission optical gratings of high diffraction efficiency in glass via irradiation with MeV-energy He^+ and N^+ ions through thick photoresist mask [1] (Bányász *et al*).

Proton beam writing has been extensively used for producing gratings and other microoptical elements in organic and inorganic optical materials [2] (Bettiol *et al*).

The aim of this work:

Imitate interferometrically produced optical gratings by producing quasi-sinusoidal refractive index profiles making use of the lateral straggling of the microbeam and by modulating irradiation fluence across the grating lines.

- Quasi-sinusoidal profile is achieved by scanning a certain line multiple times.
- 8 lines were repeated by 0, 1, 4, 7, 8, 7, 4, 1 times.
- Due to the scan resolution and FWHM of the beam the resulted red line shows the calculated profile, nearly sinusoidal.
- Grating constants of the irradiated gratings ranged from $\Lambda = 2\ \mu m$ to $15\ \mu m$.



Irradiations:

5 MV Van de Graaff at Atomki, Debrecen, HU
2μm × 2μm spot size, 2mm × 2mm scan size;
Scan resolution 2048 pixels; 2 MeV protons.

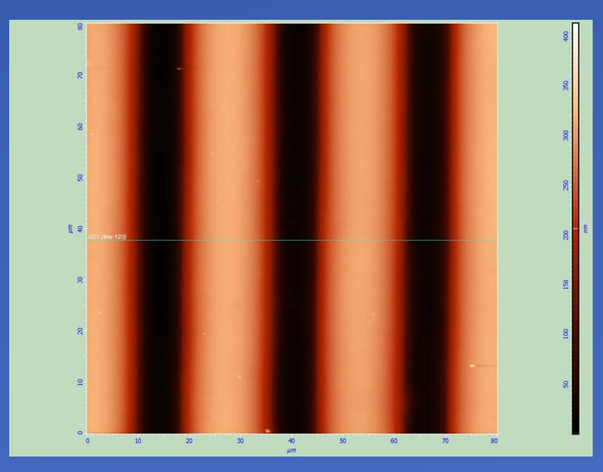
3 MV Tandetron at INP ASCR, Řež, CZ
1μm × 1μm spot size, 1mm × 1mm scan size;
Scan resolution 1024 pixels; 6 MeV C^{3+} and 11 MeV C^{4+} ions.

Fluences: $\mathbf{3 \times 10^{14} - 1 \times 10^{16}\ ions/cm^2}$

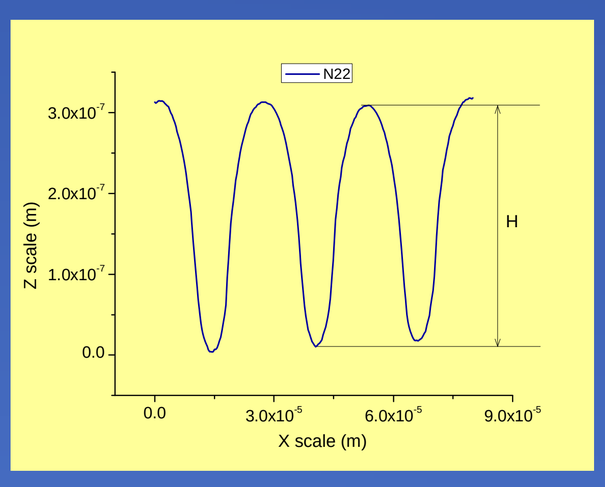
Characterization methods:

Compaction characterization by **atomic force microscopy** (**AFM**). **Interference-, phase contrast- and interference phase contrast (INTERPHAKO)** optical microscopy for measurement of integral optical path modulation. Diffraction efficiency of the gratings was also measured.

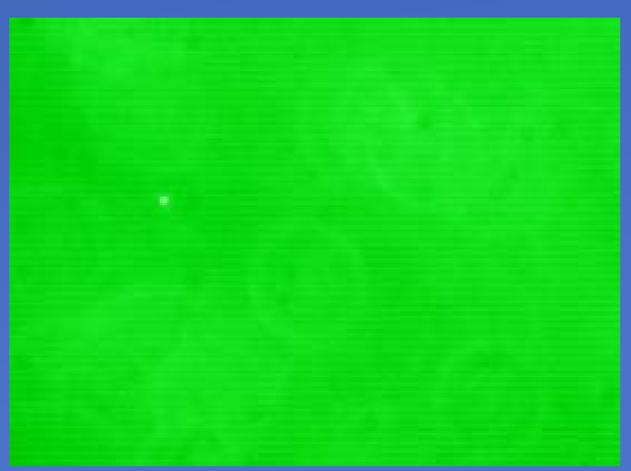
Results:



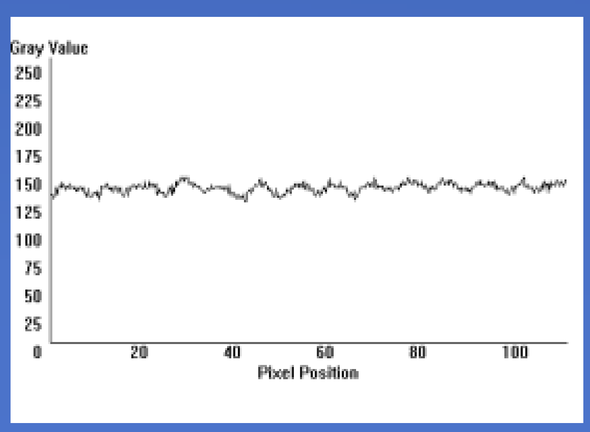
The **AFM topography image** corresponds to the surface relief grating due to target compaction (C^{3+} - written grating, $\Lambda = 8\ \mu m$).



Profile of the **AFM**. image



Phase contrast microphoto of a proton beam written grating, $\Lambda = 15\ \mu m$.



Profile of the phase contrast image

Diffraction efficiency in various orders of a proton beam written grating.

Conclusions:

Profiles of the gratings were quantitatively analysed by phase contrast - and interference phase contrast microscopies. Measured diffraction efficiency distributions in the various orders confirmed that obtained grating profiles were close to the sinusoidal.

References:

1) I. Bányász, et al, *Recording of transmission phase gratings in glass by ion implantation*, APL 79 (2001) 3755.
2) A.A. Bettiol, et al, *Embedded photonic structures fabricated in photosensitive glass using proton beam writing*, NIMB 260 (2007) 357.