Installation of a technological center for highly efficient optical gratings at Helmholtz-Zentrum Berlin (HZB)

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Abstract: In 2009 Carl Zeiss stopped the manufacture of precision gratings. All users of their gratings were very concerned about this decision, since they all need precision gratings for their experiments. One of the institutes of the HZB, the Institute for Nanometer Optics and Technology (INT), has extensive experience in micro fabrication (technology group). In spring 2010, HZB decided to take over the old C. Zeiss grating fabrication and build up its own technology center for grating fabrication. In March 2010, the INT applied to the Senate of Berlin for funding for our project from the European Regional Development Fund (ERDF). In October 2010, HZB received an approval of its application from the Senate of Berlin (contract No 20072013 2/43). Using this governmental support, HZB will install all necessary equipment and processes to fulfill these demands until end of 2013.

1. Aims

The intention of the new technology center is to develop and produce diffraction gratings for synchrotron radiation and space applications. These gratings should be generated as blazed and laminar profiles at planar, spherical, and aspherical substrates and on all common materials. Blaze angles down to 0.1 degree should be realized for such precision gratings. Mechanical ruling, Laser Holography, and Chemical and Ion etching will be installed and used as fabrication methods; additionally, modern characterization methods for gratings at-wavelength and ex-situ will also be used.

The ultimate ambition of the grating fabrication at HZB is to supply the synchrotron and space application community with high quality gratings. Carl Zeiss AG and HZB agreed in their contract to transfer the whole grating fabrication to HZB. HZB will continue the long term tradition of Zeiss and form an organisation for fabrication and sale.

After having transferred and installed of the old Zeiss equipment in Berlin, we are currently focused on the optimization of processes. At the same time, new equipment for mechanical ruling, ion etching, and measurement technology are under development. The INT and DIOS GmbH, Bad Münstereifel are cooperating in the grating fabrication. The Chair of Micro and Precision Devices of the TU Berlin is the third partner in our cooperation. This partner operates a special ruling machine.
and is able to manufacture blazed gratings on spherical and aspherical substrates as well as gratings with large blaze angles (Echelle gratings).

The cooperation partners intend to step into Zeiss Optronics shoes and want to serve the grating community with same intentions. Advisory service for customers and customer-defined gratings will be a main point in the service provided by our partners. Special knowledge is available for VLS-gratings and for gratings with several traces. Such special gratings and the distinguished service are the distinctive feature of this enterprise.

2. Fabrication Technologies

Mechanical Ruling: The main technology for grating fabrication at HZB is mechanical ruling. The workhorse of this technology is the C. Zeiss ruling engine, GTM-6. After transportation to Berlin, the machine was repaired and the mechanical and electronical components were maintained and, if necessary, replaced. The engine is installed in a thermo-stabilized cleanroom environment. The first ruled gratings were produced in December 2011. The GTM-6 is able to process substrates up to 170 mm length. A new GTM-24 is under construction. It will be delivered in summer 2013 and will be able to process substrates up to 600 mm in length.

Anisotropic Si Etching: Another interesting method for fabricating blazed gratings in silicon is chemical etching of asymmetrically cut mono-crystalline silicon. The patterning of the necessary etching mask can be done by e-beam writing or by Holography. Precondition is a precisely cut Si substrate with a super polished surface. An accurate surface cleaning is necessary for the KOH etching process.

A major challenge for the grating fabrication by wet chemical etching is the adjustment of the etching mask to the crystal planes. If reached, the Si etching method is a very cost-efficient process for generating high quality blazed gratings.
**Laser Holography:** The method is established for fabricating all kinds of laminar gratings by lithography. The resist patterning is performed by Laser interference lithography. HZB is using a UV Laser with a 442 nm wavelength. Using the Zeiss Laser optics and the Zeiss set-up, we can presently expose circular areas of about 100 mm. After transferring our set-up to a larger optical table the present limit will be overcome.

Fig. 5: Zeiss Holography set-up

Fig. 6: Si grating on 100 mm wafer, holographic exposure and wet etching, 930 lines/mm

**Mechanical Ruling by LT Ultra:** An exceptional engine from LT Ultra Precision Technology GmbH, Herdwangen-Schönach is available for the consortium to generate high precision gratings with high curvature of the sample surface. The ruling process of the LT Ultra machine is position force guided. The machine is able to generate blazed gratings at substrates with spherical or aspherical surfaces. High blaze angles can be realized (Echelle gratings). Results are shown in figs. 12 and 13.

**Characterization:** Beside the standard procedures for the characterization of gratings like AFM measurement, line density, and monochromatic wave front measurement, HZB offers at-wavelength characterization of fabricated gratings in order to determine the actual efficiency. A presently existing and a planned new reflectometer can be used for these measurements. With this instrumentation all periodic errors, the micro roughness, groove density, profile form and their variations, micro roughness of grooves, efficiency, resolution, straylight, content of higher orders, and polarization properties can be determined.

Fig. 7: New HZB reflectometer (under construction)

Fig. 8: Metrology on blazed gratings

### 3. Results
The first planar blazed test grating was ruled at HZB in December 2011. In the following weeks, the ruling process was optimized and several 5 cm long gratings on silicon substrates were generated with line densities of 650 to 2000 lines/mm. A typical result is shown in figs. 9 – 11.
4. Conclusions
The old Carl Zeiss grating equipment like the Zeiss GTM-6, Ion etcher, Laser Interference Litho set-up, and groove density measurement set-up was transferred to Berlin, installed, and re-commissioned. New HZB equipment is under development and being purchased. Presently the fabrication of laminar, blazed, and spherical gratings is possible up to a length of 150 mm.

A cooperation between HZB, DIOS GmbH, Bad Münstereifel and the Chair of Micro and Precision Devices of the TU Berlin was formed for development and fabrication of gratings. The cooperation and the recent status of the equipment and process development provide very good chances for successful operation of the old Zeiss and new HZB equipment.

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