Fabrication of pixelated wiregrid polarizers for real-time laser beam profile analysis

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The exact knowledge of the laser beam profile, wave front and polarization state is very often the criteria for an effective and long-term stable usage in industrial applications. Especially the control of the laser beam during operation of high-power lasers, e.g. in material processing, is essential. Here the thermal lens for beam guidance and focusing optics can result in a considerable deviation of the beam parameters from the targeted process values [1]. Due to the complex and transient nature of thermally induced effects, established measurement methods only cover partial aspects of the problem, which is relevant e.g. for the time-resolved analysis of stress birefringence and associated wave front deformations in thermally loaded optics [2]. A real-time measurement method for comprehensive, quantitative light field analysis could significantly reduce obstacles in the industrial use of high-power lasers.

For the high-resolution real-time acquisition of all relevant beam parameters a measuring principle based on the wave front curvature sensor was further developed and extended by the spatially resolved determination of the polarization state. In this work we report on the fabrication of a pixelated wire grid polarizer to enable this analysis technique by using nanoimprint lithography. The elementary cell of this nanogrid array consists of four gratings with different orientations covering exactly four pixels of the corresponding CCD detector (figures 1 and 2). With this new sensor, the wave front can be reconstructed either separately for each polarization direction or by averaging the four partial gratings. It is also possible to characterize the polarization state locally by determining the Stokes parameters.

The pixelated nanogratings of the polarizing element consist of 1:1 lines & spaces patterns with a pitch of 180 nm, arranged in four different orientations per elementary cell (figure 2). This polarizing element is defined in a 180 nm thick aluminum (Al) layer located on a 2 mm thick quartz substrate. The respective etch mask is fabricated by substrate conformal imprint lithography (SCIL) which allows the distortion-free replication of nanopatterns with critical dimensions well below 100 nm [3]. In order to enhance the selectivity between the aluminum and the resist etch mask, an additional silicon dioxide (SiO_2)-layer of 50 nm is deposited onto the aluminum layer acting as a hard mask during the reactive ion etching (RIE) process. The grating structures are finally transferred into the Al by a two-stage RIE process. In the first step the residual layer of the imprint resist and the SiO_2 hard mask are opened in a fluoroform (CHF_3)-based plasma. The underlying Al layer is then etched in a combined etch plasma consisting of boron trichloride (BCl_3) and chlorine (Cl_2) as main etch gases and fluoroform (CHF_3), which guarantees highest anisotropy resulting in Al lines with aspect ratios up to 3:1 and perpendicular sidewalls (see figures 3 and 4). Corresponding optical measurements of these polarizing elements resulted in polarization extinction ratios up to 389:1 at 1064 nm wavelength.

In conclusion pixelated wire grid polarizers based on Al gratings with aspect ratios up to 3:1 and extinction ratios up to 389:1 based on a fabrication process chain consisting of a distortion free SCIL feature replication and specifically tailored RIE etching processes were demonstrated.

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Reference:

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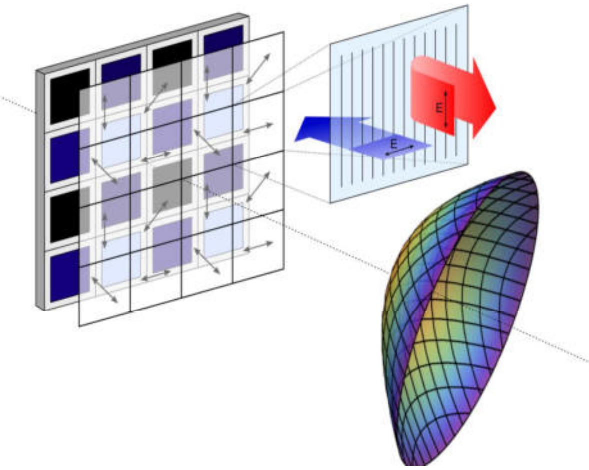

Figure 1 Schematic view of the pixelated polarizer. From left to right: CCD cell, polarizing element, polarization direction and beam profile.

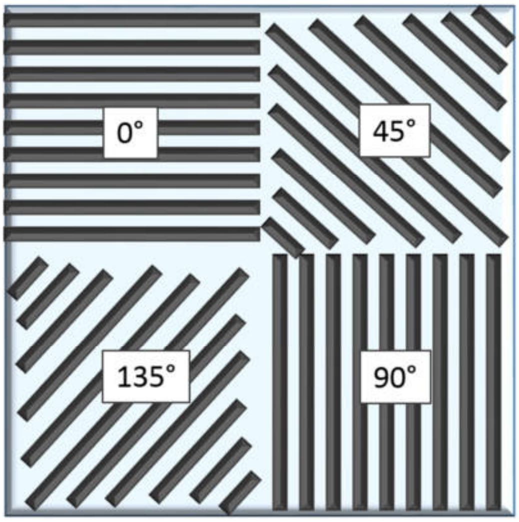

Figure 2 Schematic view of the pixelated elementary cell showing the four different grating orientations.

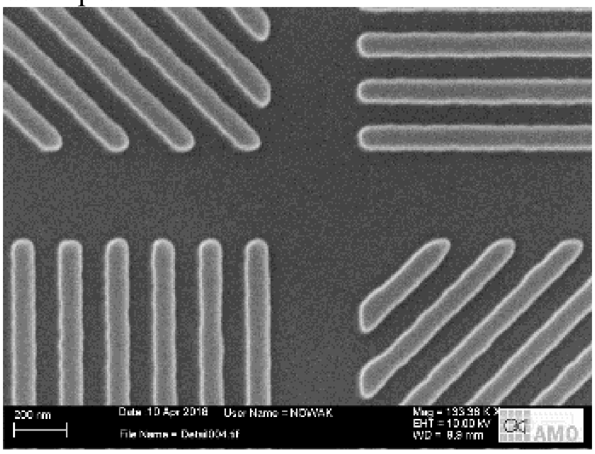

Figure 3 SEM image of the centre of the pixelated elementary cell showing the single grating blocks.

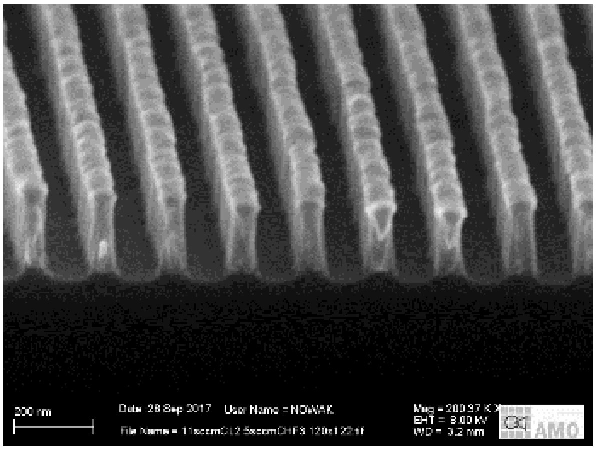

Figure 4 cross section SEM image of the nanograting defined in aluminum with a height of 200 nm and a width of 90 nm.