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H4

FABRICATION AND CHARACTERIZATION OF 1-D DIFFUSING ELEMENTS

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Abstract: *Certain high power laser applications require thin homogeneous laser lines. In this paper we describe the concept, fabrication and characterization of a 1-D diffuser that generates such a line. The device is based on an array of concave cylinder lenses with a statistically distributed width and a fix radius of curvature. The fabrication is based on isotropic wet etching of fused silica. Measurement results are compared to simulation which show good agreement.*

1. Introduction

Laser lines with a uniform flat-top profile are interesting for many applications i.e. surface treatment and fabrication (e.g. laser annealing for TFTs [1]). A possible concept to generate the necessary flat-top profile uses multi-aperture elements followed by a lens to recombine separated beamlets [2]. Advantages of this concept are the independence from entrance intensity profile and achromaticity. However, the periodic structure and the overlapping of beamlets produce interference effects especially when highly coherent light is used. Random optical elements that diffuse only in one direction reduce the contrast of the interference pattern. Losses due to undesired diffusion in large angles have to be minimized to maintain high efficiency of beam shaping.

2. Concept

The concept we present in this paper for a 1D diffuser is based on a statistical array of cylinder lenses. The lenses have a constant radius of curvature with a statistical distribution in width. In order to achieve narrow diffusion angles (1-2° FWHM) it is necessary to have lenses with a small sag. To avoid specular transmission which would result in a unwanted intensity peak it is necessary to avoid flat zones at the bottom of the lens as well as at the top.

As a material we use fused silica for its large transmission range and good damage resistivity in high power laser applications.

3. Fabrication

The fabrication is based on isotropic etching of fused silica in hydrofluoric acid (HF 49%). The fused silica is isotropically etched through apertures in an etch stop mask. As an etch stop mask we use a thin layer of poly-silicon (poly-Si). In the isotropic etch process every point inside the etch aperture is the center of a circle that propagates into the material. To simplify the model for the isotropic etch process it can be represented by two circles propagating from the etches of the aperture into the material with a flat zone with the same dimension as the aperture connecting the two circles (see Fig 1). After the etch process is completed with a desired profile, the mask has either fallen off or is removed by KOH.

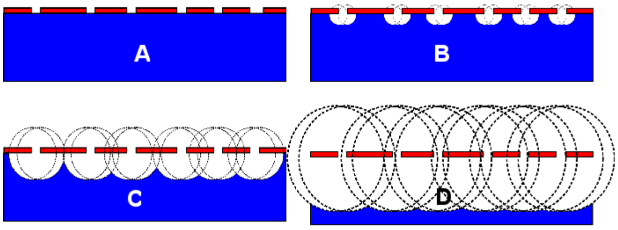

Fig 1. Isotropic etch process. Spheres of different diameters allow to evaluate the surface profile for different etching times.

In order to obtain lenses with a profile that is as circular as possible the width of the aperture should be small compared to the width of the lens. For lenses with a mean width of around 100µm an etch aperture of 1µm has proven to be a good value for patterning the poly-Si mask by photolithography and RIE and guarantee still an acceptable wetting in the HF etching process.

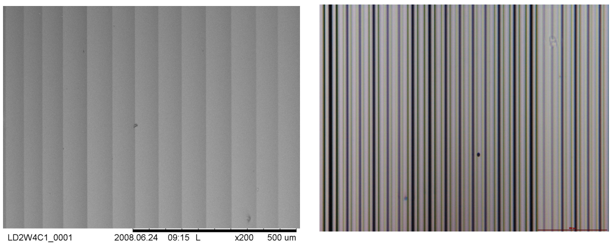

Fig 2. SEM picture (left) optical picture (right) showing the topography of the 1D diffuser.

4. Measurements

We employ a genuine goniophotometer for characterization. The setup (Fig 3) consists of a laser light source (HeNe 633 nm, 15 mW), a beam expander, a sample holder for the diffuser and a detector. The light source and sample are mounted to a rotation table and the detector is fix. This allows a high angular precision (0.01°) without the mechanical issues of a detector mounted on a rotating arm. The setup gives information on the intensity's angular distribution, the diffusion angle (FWHM), the uniformity of the diffused intensity and the intensity of the undiffused light (zero order).

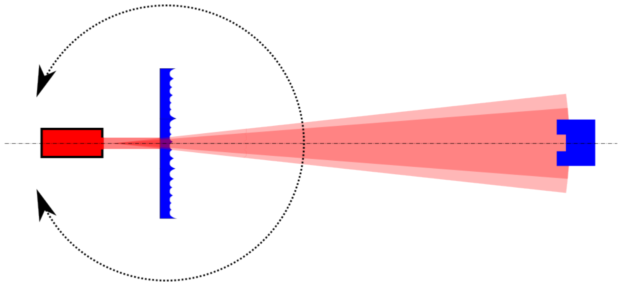

Fig 3.Goniophotometer setup. From left to right: rotation stage with laser, beam expander (not drawn) and 1D diffuser, detector with 200µm aperture. The distance diffuser-detector is 2m.

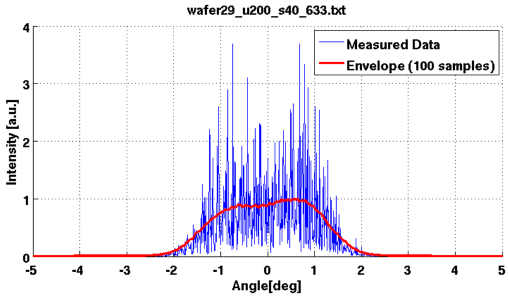

Fig 4.Goniophotometer measurement of a device with a mean lens width of 200µm and a variation of 40µm. The FWHM diffusion angle is about 1.5°.

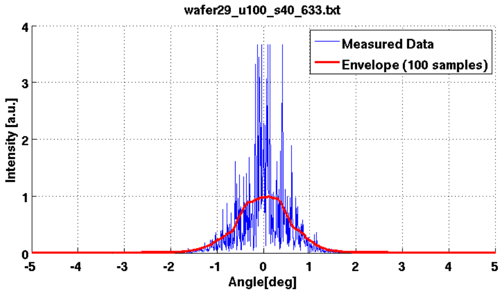

Fig 5.Goniophotometer measurement of a device with a mean lens width of 100µm and a variation of 40µm. The FWHM diffusion angle is about 0.5°.

Goniophotometer measurements of fabricated devices show an intensity envelope with the desired diffusion angle of less than 2° FWHM and superimposed a fast, irregular variation (Fig 4, Fig 5). This speckle like pattern is due to diffraction caused by the irregular grating of cylindrical microlenses. Applying a boxcar filer function makes evident that there is nearly no noticeable specular transmission (zero order) for the devices with 200µm and 100µm mean lens width.

5. Simulation

Simulation of coherent propagation was done by FRED from Photon Engineering that uses a Gaussian beam model. As a source we use a truncated Gaussian beam corresponding to the laser beam after the beam expander. The profile of the device was generated by a process simulation based on the isotropic etch model proposed above.

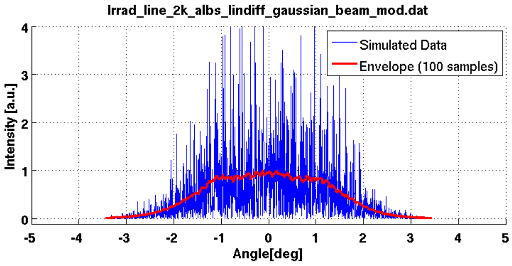

Fig 6. Simulated angular spectrum for a device with a mean lens width of 200 µm and a variation of 40µm.

The simulated angular spectrum is in very good agreement with the measured data. The FWHM diffusion angle of the simulation is slightly larger than the measurement (Fig 6).

6. Conclusions

We proposed a concept for a linear diffuser and described a fabrication process as well as characterization and simulation. Simulation showed good agreement with measurement. The devices show a narrow diffusion angle of 1-2° FWHM that can be adjusted by the design. Depending on the requirements of the application it is necessary to optimize the device more in order to obtain a smoother intensity profile. Our model based on process simulation and beam propagation gives usu the freedom to design diffusers for specific diffusion angles.

Acknowledgement

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References

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