# Method for correcting the joint error of a laser writer

**Yongjun Xie, Zhenwu Lu, and Fengyou Li**

*State Key Laboratory of Applied Optics, Changchun Institute of Optics and Fine Mechanics and Physics, Chinese Academy of Sciences, Changchun 130022, China*
luzw@sklao.ac.cn

**Abstract:** We present what we believe to be a new method for correcting the joint error of a laser writer without reduction of throughput. By digitization, we optimize the intensity data of the incident beam at the vicinity of the start point and the end point. The joint error will not be sensitive to lengthening of the start or end point by optimization. The advantage of this method over multipass writing and error scattering is that it requires only a single pass, and thus 80% of the fabrication time will be saved. Experimentation shows the method to be effective.



**OCIS codes:** (220.3740) Lithography; (050.1970) Diffractive optics

## References and links

1. D. B. Chrisey, "The power of direct writing," Science **289**, 879-881 (2000).
2. D. Bauerle, *Laser Processing and Chemistry*, 2nd. ed. (Springer-Verlag, Berlin, 1996).
3. S. M. Metev and V. P. Veiko, *Laser-Assisted Micro-Technology*, 2nd, ed. (Springer-Verlag, Berlin, 1998).
4. W. Yu, X. C. Yuan, N. Q. Ngo, W. Que, W. C. Cheong, and V. Koudriachov, "Single-step fabrication of continuous surface relief micro-optical elements in hybrid sol-gel glass by laser direct writing," Opt. Express **10**, 443-448 (2002), http://www.opticsexpress.org/abstract.cfm?URI=OPEX-10-10-443.
5. Y. Xie, Z. Lu, F. Li, J. Zhao, and Z. Weng, "Lithographic fabrication of large diffractive optical elements on a concave lens surface," Opt. Express **10**, 1043-047 (2002), http://www.opticsexpress.org/abstract.cfm?URI=OPEX-10-20-1043.
6. W. H. Hamaker, G. Burns, and P. Buch, "Optimizing the use of multipass printing to minimize printing errors in advanced laser reticle-writing systems," in *15th Annual BACUS Symposium on Photomask Technology and Management*, G. Shelden and J. Wiley, eds., Proc. SPIE **2621**, 319-328 (1995).
7. A. Poleshchuk and J. Burge, "Polar coordinate writing systems: error analysis of fabricated DOEs," in *Lithographic and Micromachining Techniques for Optical component Fabrication*, E.-B. Kley and H. Peter Herzig, eds., Proc. SPIE **4440**, 161-172 (2001).
8. J. R. Salgueiro, V. Moreno, and J. Linares , "Model of linewidth for laser writing on a photoresist," Appl. Opt. **41**, 895-901 (2002).

## 1. Introduction

Direct-writing technologies are of increasing importance in materials processing [1]. Direct-writing technologies, in which structures are built directly without the use of masks, allow for rapid prototyping. Direct writing by a focused laser beam, in which accurate control of the process parameters enables a complex continuous-relief microstructure to be fabricated in a single-exposure scan and development step, is valued by researchers because of its broad application to surface science and material processing (annealing, deposition, micromachining, microfabrication of diffractive elements, and so on) [2–4]. Direct writing has significant advantages (writing area and scanning speed) over the electron-beam direct-writing technology for the fabrication of large diffractive optical elements (DOEs) on a curved surface with precise alignment [5]. Some of its well-known characteristics, which make it attractive, are low cost, technical simplicity, and good quality of the structures patterned.

Correcting joint error is indispensable in the process of fabricating DOEs with a laser writer. At present, joint error is always corrected by the method of multipass writing and error scattering. However, this method reduces the throughput of the laser writer [6,7]. It is not tolerable to the manufacturer to fabricate large DOEs with thousands of lines or circles [5]. In


Received March 27, 2003; Revised April 15, 2003

this paper, we present what to our knowledge is a novel method for correcting the joint error of a laser writer without reduction of throughput.

## 2. Correction method

The phenomenon of joint error is shown in Fig. 1. It can be seen from the figure that the end-of-the-line profile is cylindrical and that its diameter is equal to the linewidth. We can predict that lengthening of the start point or end point can correct the joint error without decrease of fabrication efficiency. However, it is not possible to control this lengthening because of the cylindrical profile of the line's start and end points. Three instances of the joint lengthening are shown in Fig. 2.

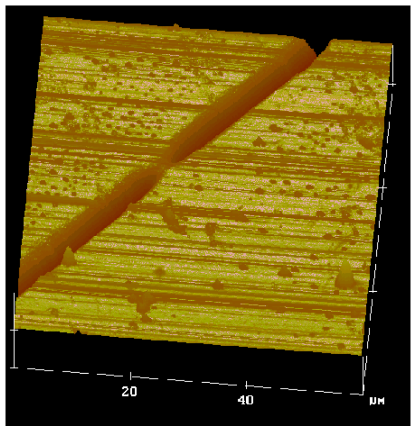
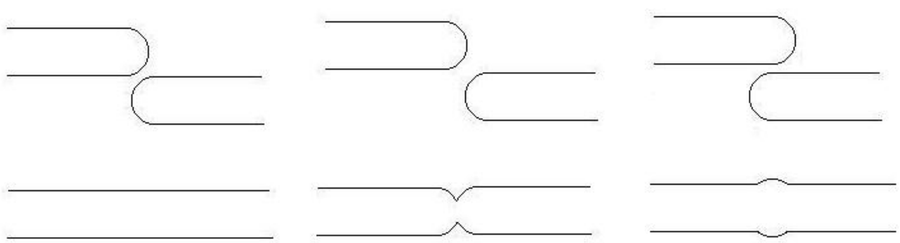



Fig. 1. Phenomena of joint error.



(a) (b) (c)

Fig. 2. Three instances of the joint. (a) Correct lengthening. (b) Insufficient lengthening. (c) Excessive lengthening.

The example in Fig. 2(b) or Fig. 2(c) appears frequently in the experiment, whereas the example in Fig. 2(a) appears infrequently. The method of multipass writing and error scattering can correct this error effectively at the cost of decrease in efficiency [6,7]. However, it is not tolerable to the manufacturer to fabricate large circular DOEs with thousands of circles or lines [5]. Here we present a new method to correct this error effectively without decrease of fabrication efficiency.

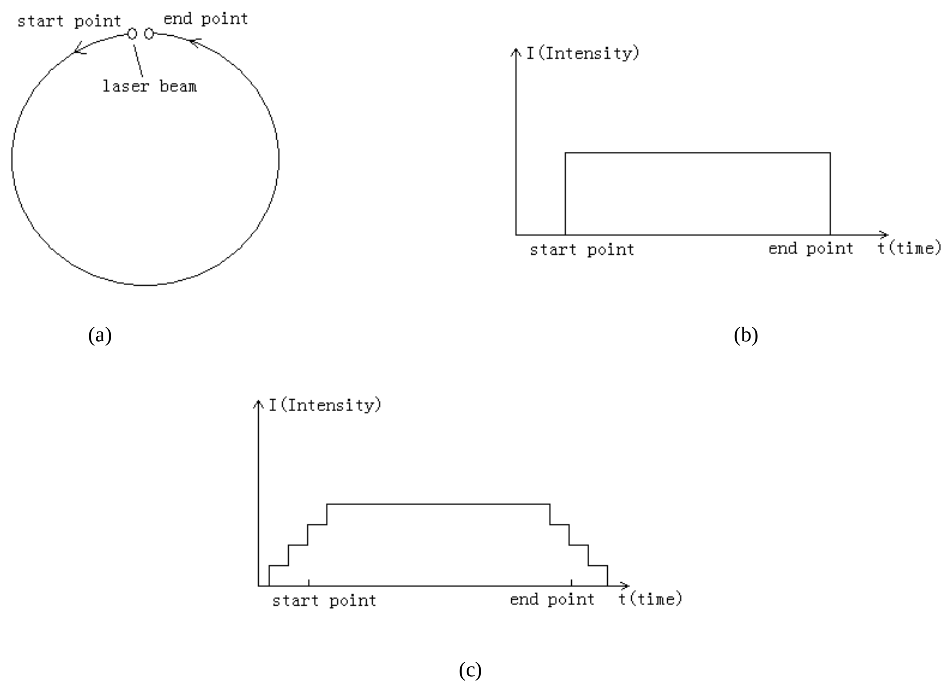



Fig. 3. Schematic of the correction process. (a) Writing one circle by a single pass. (b) Light intensity control of writing one circle by a single pass before digitization. (c) Light intensity control of writing one circle by a single pass after digitization.

Figure 3 shows a schematic of our correction method. The writing process of one circle by a single pass of the laser writer is shown in Fig. 3(a). It can be seen from Fig. 3(a) that the joint error will emerge at the vicinity of the start point and the end point. The intensity control process of writing one circle by a single pass of the laser writer is shown in Fig. 3(b). The intensity increases and decreases steeply at the start and end points. To correct the joint error, we optimize the intensity data of the incidence beam at the vicinity of start point and end points. As shown in Fig. 3(c), the intensity is digitized to several levels, and then it increases and decreases more gradually. The advantage of this digitization is that the joint error will not be sensitive to the lengthening of the start point or end point. For instance, the intensity is digitized to four levels with a length of 6 μm, and the exposure dose error will be only 25% within the lengthening error of 2 μm. Controlling the lengthening is made easy by the digitization.

## 3. Experimentation

A schematic diagram of our laser direct-writing system is shown in Fig. 4. It should be noted that we used a 150-mW He–Cd laser at a wavelength of 442 nm. Stage or laser beam movement was controlled to a precision of 0.1 μm in three Cartesian axes by use of feedback from distance measurements with linear encoders from Heidenhain GmbH. The angular velocity of the air-bearing spindle can range from 60 to 600 rpm. There are four types of diameter of writing spot to select: 1, 2, 5, and 10 μm.

#2281 - $15.00 US
Received March 27, 2003; Revised April 15, 2003

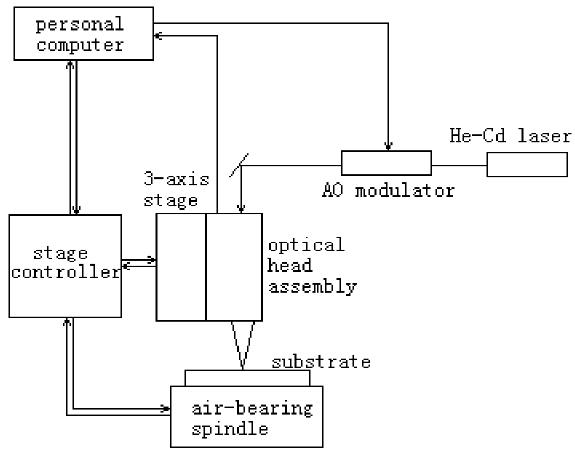
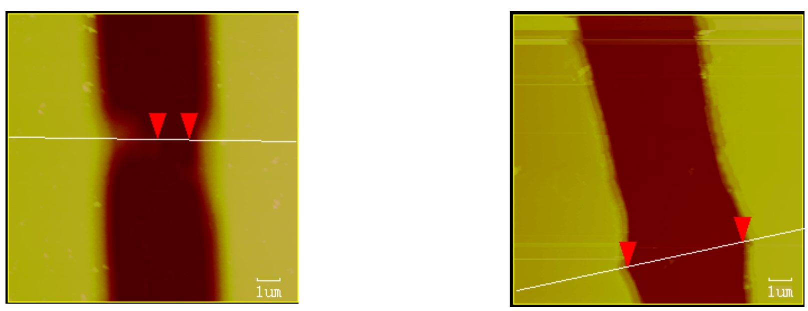



Fig. 4. Schematic of our laser direct writer.

We prepared the substrates by spin coating microscope slides with diluted Shipley S1805 photoresist at 2000 rpm to obtain a film that was ~0.5 µm thick. Before UV exposure, we prebaked the sample in an oven at 90 °C for 30 min to remove the excess solvent and to improve the adhesion of film to substrate.

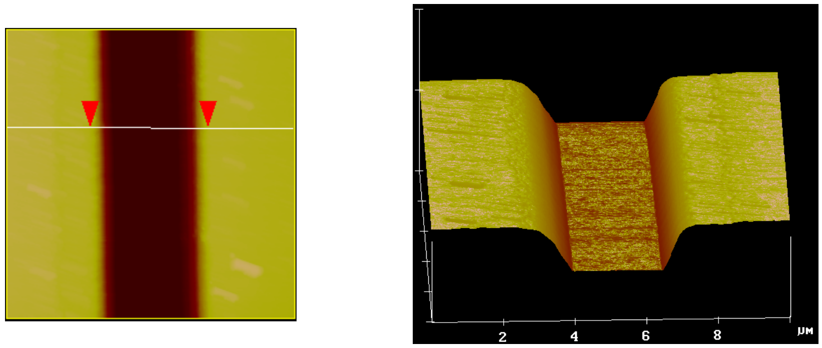



(a) (b)

Fig. 5. Experimentation of lengthening before digitization. (a) Insufficient lengthening. (b) Excessive lengthening.

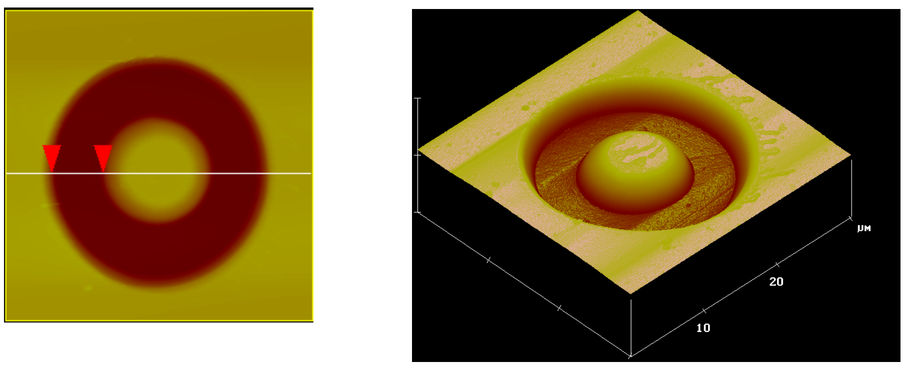
Figure 5 shows the experimental result of joint error by lengthening the end point without digitization. Figure 5(a) is an example of insufficient lengthening; Fig. 5(b), of excessive lengthening. It can be seen from Fig. 5 that these two instances are all intolerable to the manufacturer.

We digitized the start and end points in six levels at a length of 8 µm. The correction result is shown in Figs. 6 and 7. Figure 6 shows the joint of a straight line, and Fig. 7 shows the joint of a circle. It can be seen from Figs. 6 and 7 that this method is effective.




(a) (b)

Fig. 6. Correcting the line by digitization. Two-dimensional profile of the line. Three-dimensional profile of the line.




(a) (b)

Fig. 7. Correcting the circle by digitization. (a) Two-dimensional profile of the circle. (b) Three-dimensional profile of the circle.

## 4. Conclusions

Compared with multipass writing and error scattering, the advantage of our digitization method is that it needs only a single pass. In the case of fabricating large DOEs by a laser writer, there will be thousands of lines or circles, and the fabrication process will require tens of hours. By our method, the time will be reduced to approximately one fifth that of multipass. Our method is also useful for people working in other fields, such as integrated optics [8].

## Acknowledgments

This study is supported in part by the National Natural Science Foundation (60078006), the Innovation Foundation of Chinese Academy of Science (2002LQ4), and the State Key Laboratory of Applied Optics of the Chinese Academy of Science.