DEVELOPMENT OF HIGH PRECISION GLASS SCALE GRATINGS USING ULTRA FAST PULSED LASER

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Abstract: *Standard glass scale is just like a kind of very precise ruler and on its surface, accurate divisions are equally marked. The standard glass scales are frequently used in calibration of precise instruments with non contact method of measurements like optical microscopes, video microscopes, profile projectors etc. With the help of ultra fast pulsed laser micromachining system devised a state of the art process for manufacturing standard glass scales. The machined standard scales were calibrated using F25 CMM for 10 mm range scale and Profile projector for 150 mm range scale. The results of the calibration shows the accuracy of the Glass scales at par with the scales manufactured by photolithography process.*

Key words: *Standard Glass Scale, Gratings, Stage Micrometers, Ultra Fast Pulsed Laser*

1. INTRODUCTION

Normally the standard glass scale gratings were manufactured with chromium on glass by microelectronic mechanical system (MEMS) technology with photolithography [1]. However, photolithography is an expensive and complex technique. Generally, photolithography relies on expensive and precise instrumentation operated in an extreme clean room environment. Nevertheless, these requirements of photolithography technology are usually not met in most labs. Furthermore, the photolithography technology wastes so much time, that is why not readily used for commercial production [2]. Moreover, micromachining is an alternative flexible technique commercially used with miniature precision milling machines or precision laser devices [3].

Fig 1. Laser Micromachining System

2. MANUFACTURING PROCESS

2.1 Experimental Setup

The machining of high precision gratings on BK7 glass was done using Ti:sapphire Ultra fast pulsed laser micromachining system (Clark MXR, USA). Technical specifications of the system is given in Table 1.

2.2 Technical Specifications of Ultrafast Laser System

Table 1:

Technical Specifications	
Wavelength	775 nm
Laser Output	1 W
Pulse Width	10 ps to 150 fs
Min. feature size	1 µm
Repetition Rate	1 Hz to 2 KHz
Traverse X, Y & Z	150 x 150 x 100 mm
Resolution	1 nm

2.3 PROCESS

The standard glass scale fabrication requirement on its surface contains highly accurate divisions marked by ultra fast pulsed laser.

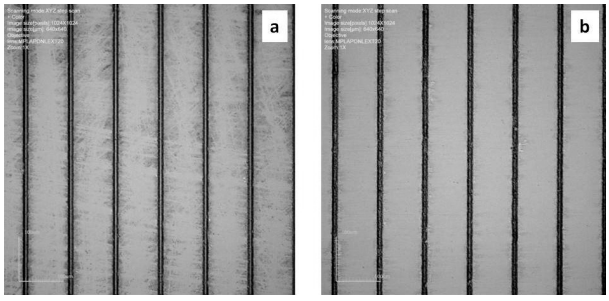


Fig 2. Confocal Image of Machined Gratings on the Glass (a) Before and (b) After Laser Optimization

The machining process involves direct writing of the gratings on the glass surface using ultra fast pulsed laser. The process requires optimization of the laser parameters like laser power, pulse width, feed rate etc to achieve the required gratings depth, accuracy and surface finish of marking. Figure 2 shows the confocal images of the laser machined gratings before and after laser parameters optimization.

Figure 3(a) shows non-uniformity in gratings depth before laser optimization and Figure 3(b) shows a uniform depth of gratings after optimization of laser machining parameters. During optimization laser parameters varied as follows: The laser power varied between 1mW to 10mW, Pulse width varied from 10 ps to 150 fs, feed rate varied from 0.5 mm/sec

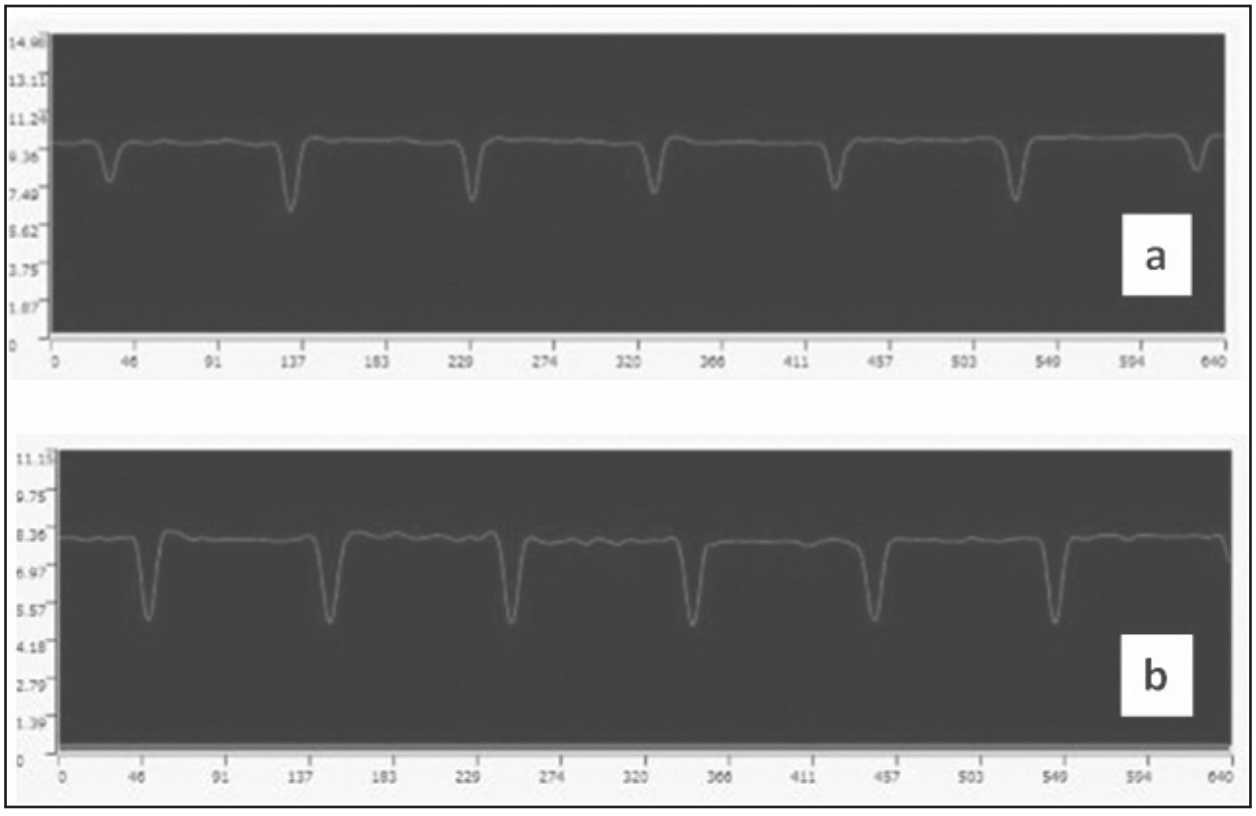


Fig 3. Variation in Gratings Depth (a) before and (b) after Laser Optimization

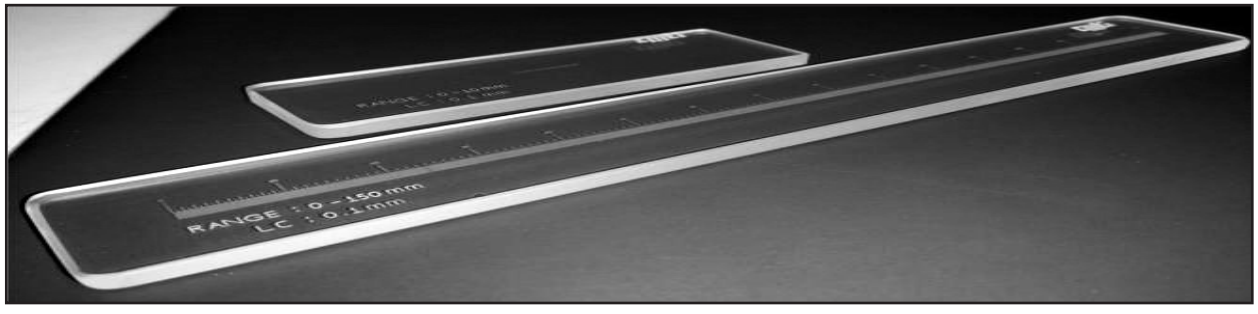


Fig 4. Standard Glass Scales Developed in CMTI

to 5 mm/sec keeping the repetition rate constant at 2 kHz.

Figure 4 shows the image of standard glass scales developed in CMTI using ultra fast pulsed laser system. Figure 5 shows an image of standard scale manufactured by photolithography technique.

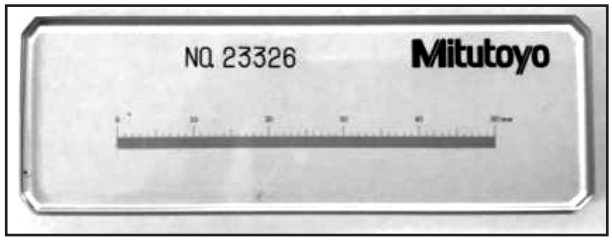


Fig 5. Standard Glass Scale by Photolithography Process
Courtesy of Mitutoyo South Asia, Bengaluru

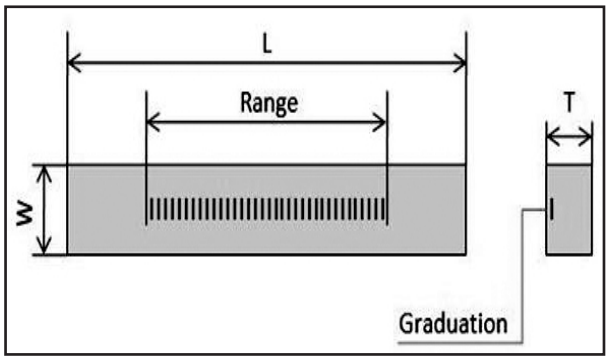
3. TECHNICAL DATA OF SCALES

Glass Material	: BK-7
Thermal Expansion coefficient	: 7.5 X 10^{-6} / K
Density	: 2.51 g/cm^3
Graduation Pitch	: 0.1 mm
Graduation thickness	: 12 µm
Gratings depth	: 3 µm
Grating Accuracy	: < 2 µm

3.1. Material

BK7 is high quality optical glass that is used for glass scale fabrication whenever the additional benefits of fused silica and fused quartz (like for example for high transmission outputs in the UV-C light section and deep IR-light) are not required [4]. This material performs well in all chemical tests and no special handling is required. The material is also relatively hard with an extremely low bubble and inclusion content.

3.2. Specifications



Metric

Range	L	W	T
0-150 mm	175 mm	20 mm	5 mm
0-10 mm	75 mm	20mm	5 mm

4. RESULTS & CONCLUSIONS

The machined standard scale (Range: 0-10 mm, 1 Division : 0,1 mm) was calibrated using Ultra precision coordinate measuring machine (Model : F-25) and the results were tabulated as shown in Table 2 below.

Table 2:

Sl. No	Glass Scale Reading	Calibrated Values	Error
1	0	0	0.0000
2	0.10	0.0999	-0.0001
3	0.20	0.2000	0.0000
4	0.30	0.2999	-0.0001
5	0.40	0.4007	0.0007
6	0.50	0.4999	-0.0001
7	0.60	0.6009	0.0009
8	0.70	0.7001	0.0001
9	0.80	0.8004	0.0004
10	0.90	0.9000	0.0000
11	1.00	1.0008	0.0008
12	1.50	1.5001	0.0001
13	2.00	2.0004	0.0004
14	2.50	2.5010	0.0010
15	3.00	3.0003	0.0003
16	3.50	3.5001	0.0001
17	4.00	4.0008	0.0008
18	4.50	4.5015	0.0015
19	5.00	5.0003	0.0003
20	6.00	6.0013	0.0013
21	7.00	7.0000	0.0000
22	8.00	7.9999	-0.0001
23	9.00	9.0008	0.0008
24	10.00	10.0012	0.0012

The results of the calibration shows that the grating pitch accuracy less than 1 µm and the straightness of the gratings are found to be within 1 µm.

The standard glass scale gratings manufactured by CMTI using ultra fast pulsed laser is at par with glass scale gratings manufactured

by photolithography technique. In ultra fast laser machining method one of custom made scales can be produced at the competitive price with high accuracy and varying sized depending on the application requirement.

5. REFERENCES

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Dr. N Balashanmugam obtained PhD degree from National Institute of Technology (NITK), Surathkal. For his PhD degree, he worked on polymer micro needles based electrodes for bio-potential measurement. He was a UNIDO fellow at Lehigh University, Bethlehem, Pennsylvania, USA.

Since 1986, he has been working in Central Manufacturing Technology Institute, Bengaluru and had involved in development of more than fifty prototypes of machines and special purpose machines in CMTI. He had pioneered in introducing concepts of Group Technology (GT) in machine tool prototype manufacturing. He was also instrumental in development of technological process for manufacture of low pressure and high pressure filter head units for Light Compact Aircraft.

Dr. N Balashanmugam has made vital contributions towards establishment of Nano Manufacturing Technology Centre, first of a kind mega project in India. Also, as a principle investigator, he had spearheaded translational research in indigenous development of Micro stereolithography system, Abrasive flow finishing machine, Magnetic abrasive finishing system and Micro needles for Bio-potential measurement. He had provided consultancy to Tata Growth Shop., Jamshedpur, Kirloskar brothers Ltd., Sangli and Adler Med equip Pvt. Ltd., Pune. He has two inventions (patent pending) to his credit and published many papers in Journals and Conferences. He is a member and Convener of Research Advisory Board of CMTI, member of research advisory committee of Atriya Institute of Technology, Bangalore and executive member of Metrology Society of India Southern Region.