Beam shaping and femtosecond laser processing

Ultrafast Photonics Lab

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Abstract

This project centers on constructing a Michelson interferometer for a pulse Laser glass welding system to assess the stability of the 3-axis stage and examine the quality of Bessel beams derived from Gaussian beams via an axicon. The preference for Bessel beams is rooted in their superior focal-position tolerance for glass welding.

Experimental design

1. Assessing stage stability using a Michelson interferometer, which sensitive to path length differences, helps determine the necessity of utilizing Bessel beams based on interference pattern changes.

2. Gaussian and Bessel beams exhibit distinct profiles. Bessel beams, with a wider focal-position tolerance and less FWHM stretch, will be assessed by measuring its profiles.

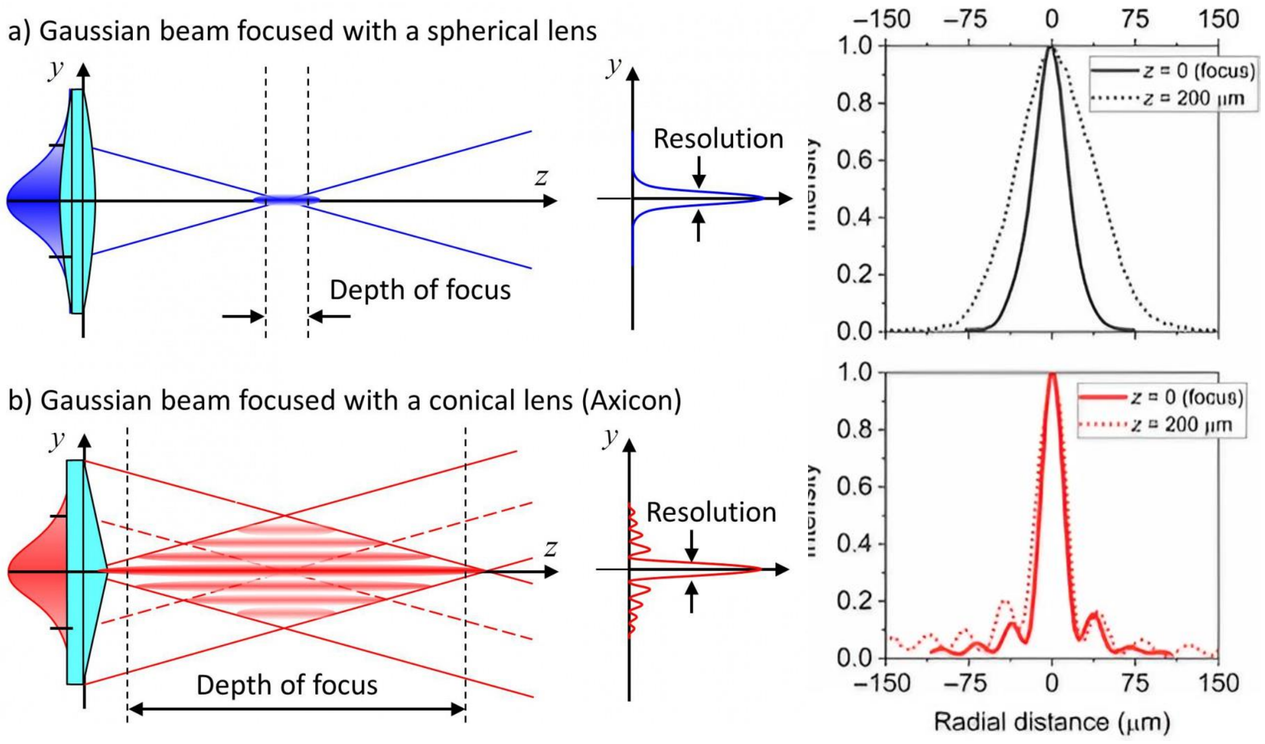


Fig. 1 Diagram comparing Gaussian and Bessel beams.[1][2]

3. Conduct glass welding

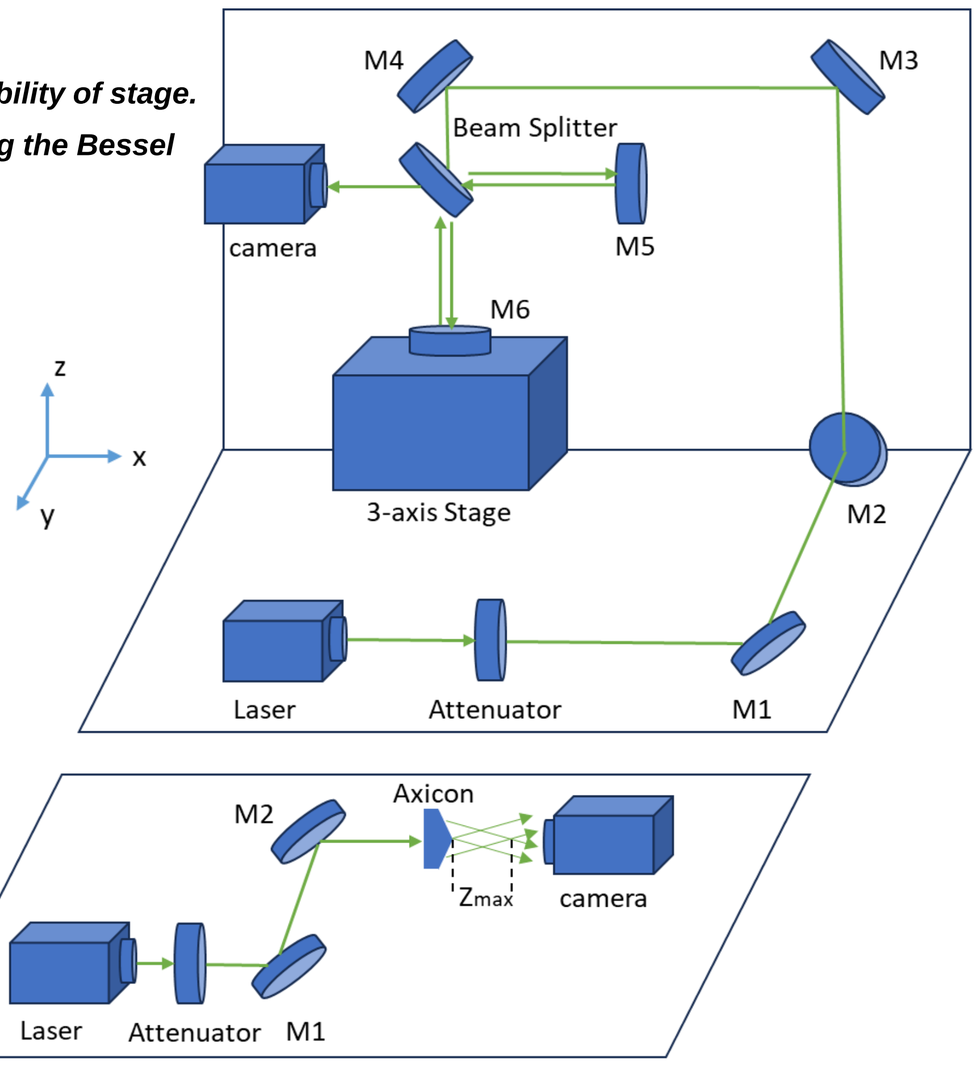
Utilize Femtosecond laser
→ Non-linear absorption
→ Multi-photon absorption and Avalanche ionization
→ Temperature increasing locally

Setup

Fig. 2 The setup :

(top) Exam the stability of stage.

(bottom) Measuring the Bessel beams' profile.



Green CW laser (532nm, D = 2.5mm); Axicon (n = 1.458, α = 10°); Z_{max} = 1.563cm

Result & Discussion

Exam the stability of stage, which the accuracy requirements of glass welding usually in micro meter level[3].

Initially, aligning unfocused beams reveals perturbations in the pattern with stage movement, but the exact path length difference remains uncertain.

Next, focusing the beams and creating slight separation exposes fringes of equal thickness. Observing the transition from one bright stripe to the next at same region, we estimate the path length difference on z-axis as an integer multiple of λ/2.

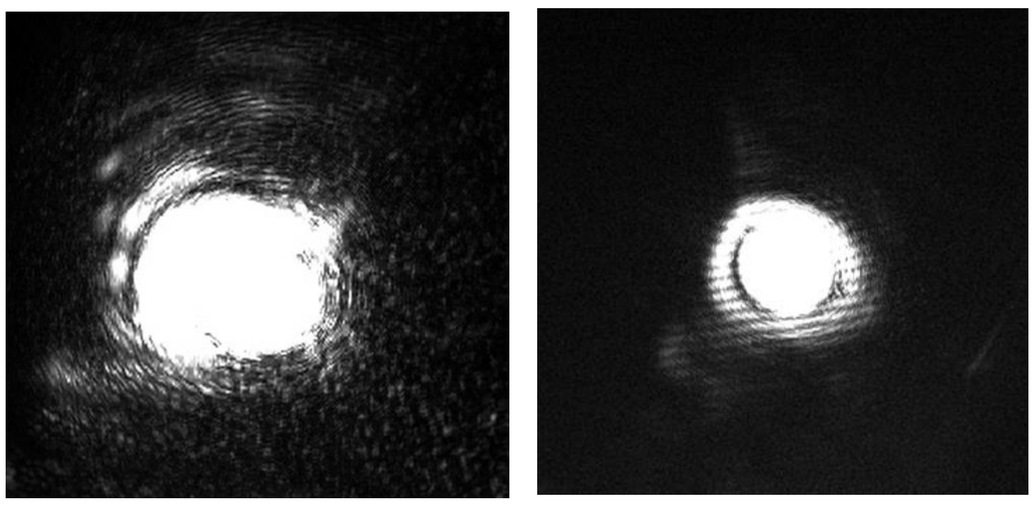


Fig. 3 The interference patten(left) and fringes(right)
Stage moves on XY plane at 6.15 μm/s for totally 0.4mm distance

In measuring the Bessel beams' profile derived from Gaussian beams via an axicon, upon lens measurement of its profile, intriguing features emerged beyond the central lobe, notably a series of concentric rings.

By further attenuate the beams, we can see more clear detail of the patten, which has a cruciform distortion.

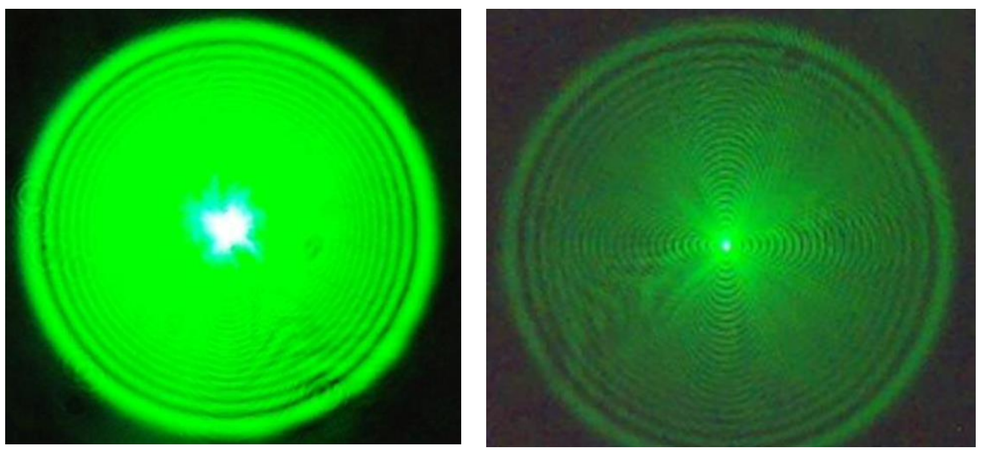


Fig. 4 The central lobe of Bessel beam(left) and attenuated patten(right)

Conclusion & Future work

- ❏ Path length difference on z-axis existed as an integer multiple of λ/2, we can do further measurement to know exact displacement.
- ❏ Cruciform distortion of Bessel beam is observed, we can comparing our experimental results with theoretical models for further analysis.
- ❏ Future steps include employing both Gaussian and Bessel beams in varied glass welding experiments of parameters, with results compared through non-destructive measurement and destructive stress testing.

Reference :

[1] https://www.photometrics.com/learn/light-sheet-microscopy/lattice-light-sheet
[2] Thejaswi U. Tumkur, Thomas Voisin, Rongpei Shi, Philip J. Depond, Tien T. Roehling, Sheldon Wu, Michael F. Crumb, John D. Roehling, Gabe Guss, Saad A.Khairallah, Manyalibo J. Matthews, "Nondiffractive beam shaping for enhanced optothermal control in metal additive manufacturing" SCIENCE ADVANCES, Vol 7, Issue.38, Sep2021
[3] Guodong Zhang, Razvan Stoian, Wei Zhao, and Guanghua Cheng, "Femtosecond laser Bessel beam welding of transparent to non-transparent materials with large focal-position tolerant zone", OPTICS EXPRESS | Vol. 26, No. 2 | 22 Jan 2018

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