Knife edges technique for focused beam profiling of the photothermal imaging system

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Abstract. In this paper, we demonstrate knife edge techniques for measuring the focused beam profile of the photothermal imaging system. This quick and simple method of profiling the focused beam from Helium-Neon (He-Ne) laser is presented and detected by the PVDF thin film as a sensor. The study of focused beam profile is crucial so as to provide information of the focused beam such as beam resolution, depth of focus and the level of astigmatism of the beam. In knife edge technique, the blade moves across the beam in x and y-direction at varying axial position.

1. Introduction

Performing of beam profile plays the main role in characterize of laser beam because the beam profile provides information about beam resolution, depth of focus as well as the level of astigmatism of the focused beam particularly in an imaging system. In general, there are two types of techniques in characterizing the beam profile, i.e. camera based technique and scanning aperture technique. In camera based technique allows the beam profile to be measured directly in two-dimensional [1]. This technique can be done in real-time, and it only suitable for the visible up to near-infrared spectral range. It also has low saturation and damage threshold levels, which often requires considerable attenuation. Camera based systems work with larger beams and either pulsed or CW laser.

For scanning aperture technique, the light passing through is measured by a detector and correlated with the position of the aperture as it crosses the beam. Scanning aperture techniques includes the pinhole technique [2], the slit technique [3] and knife-edge technique [4]. In pinhole profiles use small pinhole as the aperture and plot the transmitted power against the position. The determination of the profile is dictated by the size of the aperture. In slit profile utilize long and narrow aperture which encompassed the full width of the beam in a direction perpendicular to the travel of the slit. However, in knife-edge technique, the aperture using sharp and straight edge like knife-edge or blade is passed through the beam. The opaque side the knife blocks out a part of the beam, while the power of the transmitted part of the beam is measured by a detector. The transmitted power for different positions of the knife edge is obtained by scanning the knife edge transversely across the beam along the orthogonal direction to the edge [4]. The knife edge technique is a beam profiling method to determine the beam width of focus beam by assuming the incoming beam is having a Gaussian beam profile [5]. The knife-edge technique is the most popular, cheap and quick technique. It is most useful with very small beams, CW laser and high power laser. However, the drawback of this technique has been the increase of error since to differentiation the step response function (SRF) [6] which will amplify the
noise. By fitting Gaussian equation into SRF and extract the beam widths of the beam focus. In this section, the step of knife-edge technique for characterizing the focused beam profile is described.

2. Experimental
The schematic diagram of knife-edge technique experimental is shown in figure 1. The beam of 150mW He-Ne laser modulated by variable frequency optical chopper (SR540) is impinged onto the PVDF film supported by 1.2 cm thick Perspex backing. The output from the pyroelectric detector is fed into a lock-in amplifier (SR530) for signal analysis. Frequency optical chopper is to give pulse laser at 5 Hz frequency modulation.

For the setting up of knife edge technique, a blade is used to measure beam’s diameter. The blade was mounted on top of the motorized translation stage. There will give two types of translation, which included longitudinal displacement (z-direction) and the transversal movement (x and y direction). In transversal stages, the translation was mounted to be perpendicular. Besides, the knife edge pair was mounted on the transversal stage and they should align correctly with the ground.

To study the beam profile of the focused beam, a radiation–blocking plate was mounted on a computer-controlled two-dimensional translation stage. This plate was moved across the beam in x (horizontal) and y (vertical) orientation at different position along the z-axis beam using 0.5 mm step size. The step responses for both orientations were recorded, allowing step response function (SRF) to be plotted.

![Figure 1. Schematic diagram of knife-edge experimental setup](image)

3. Results and discussion
The trend of intensity that obtained against the x position and y position are still in the Gaussian pattern which assumed that it is the Gaussian beam profile for this research. In order to obtain the beam width of horizontal and vertical orientation, the expression is given by:

\[
p = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} I(x, y) \, dx \, dy = \frac{p_0}{2} \text{erfc} \left( \frac{a\sqrt{2}}{w} \right)
\]

Where \(I(x,y)\) is the intensity level at \(x\) and \(y\) position of the beam that perpendicular to \(z\) axis which is the direction of propagation \(\text{erfc}(a\sqrt{2}/w)\) is an integral of Gaussian.

The fraction \(p/p_0\) rely on the term \((a\sqrt{2}/w)\) where \(a\) and \(w\) indicate the position of the knife edge and the beam width, respectively. The SRF for the both orientations, show that the fitting for
transmitted power against x-axis labelled $x - x_0/\omega$, where $x_0$ the beam center and $x$ is the distance from the beam center. The gradient of the curve $p/p_0$ is related to the beam width, where the shallower the gradient of $p/p_0$ is the larger the beam width [6].

Figure 2 shows the SRF at different position along the beam axis for both horizontal and vertical orientation, at a frequency of 5 Hz. The SRF at position 5 cm, measured from a beam focus shows the maximum gradient in both horizontal and vertical orientation representing the minimum beam width of the beam focus.

![Figure 2](image.png)

**Figure 2**: Step response function (SRF) of (a) horizontal and (b) vertical orientations.

![Figure 3](image.png)

**Figure 3**: Example of fitting equation to the experimental data to find the beam width in the vertical (y) direction, at a beam axis of 5 cm, measured from the beam focus.
Figure 4 shows the beam width deduced from the SRF in (a) horizontal and (b) vertical directions. The minimum beam width for both orientations was 0.7386 mm in the horizontal and 0.6871 mm in the vertical. The astigmatic difference is the difference between minimum beam waist in the horizontal and vertical orientation is 0.0515 mm. This astigmatism effect was expected, probably due to the beam is not propagated through the center of the mirror.

![Figure 4](image)

**Figure 4**: Beam width $w$ obtained from Gaussian fits to the experimental data for (a) horizontal and (b) vertical orientation

4. **Conclusion**
In conclusion, the size of the beam focus of the imaging system was characterized along the beam axis using the knife edge technique. The beam width of the focused beam in horizontal and vertical were 0.7386 mm and 0.6871 mm respectively, with small astigmatism effect.

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**References**
[1] Siegman A E 1998 How to (Maybe) Measure Laser Beam Quality *DPSS (Diode Pumped Solid State) Lasers: Applications and Issues*
[2] Boley C D, Estabrook K G, Auerbach J M, Feit M D and Rubenchik A M 1999 Third International Conference on *Solid State Lasers for Application to Inertial Confinement Fusion*
[3] Chapple P B 1994 *Optical Engineering* **33** 2461
[4] González-Cardel M, Argújo P and Díaz-Uribe R 2013 *Applied Optics* **52** 3849
[5] Khosrofian J M and Garetz B A 1983 *Applied Optics* **22** 3406
[6] Saat N K, Dean P, Khanna S P, Salih M, Linfield E H and Davies A G 2016 *Jurnal Teknologi* **78**
[7] Araújo M A D, Silva R, Lima E D, Pereira D P and Oliveira P C D 2009 *Applied Optics* **48** 393