L.7: Scanning pixel technique for measurement of small spot-size of laser beams

A new technique for measurement of a laser beam spot-size smaller than the size of a CCD-pixel has been demonstrated at Laser Physics Applications Division, RRCAT *[Meas. Sci. Technol. 21 (2) 025308 (2010)]*. This technique can be used to measure spot-size of a beam of known intensity profile. It involves scanning a CCD-pixel transverse to the beam axis and recording the variation in number of counts on the pixel with position. This observed variation in counts with position is fitted with a simulated variation of power incident on the pixel. The beam spot-size which governs intensity profile is used as a parameter in the simulations, and its value is obtained from the best fit between simulated and observed data. Besides simplicity and sub-pixel accuracy, the above scanning pixel technique is particularly attractive for measuring size of central spot of a Bessel beam for which familiar scanning knife-edge technique does not work due to large contribution of side rings to the signal.

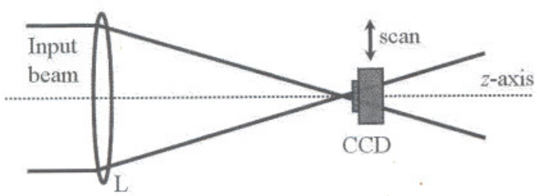

Fig. L.7.1. Schematic of experimental setup of scanning pixel technique

In the proposed technique, we measure the number of counts on a pixel which is proportional to the power incident on that pixel. Thus, variation in counts on a pixel with its position across the beam represents the variation of power incident on the pixel with position. This power P over an area element of the size of a pixel, positioned at $(x_o,0,z)$ at a distance x_o from the beam axis (z-axis), can be evaluated as,

$$P(x_0,\alpha) = \int_{-a+x_0}^{a+x_0} \int_{-a}^{a} I(x,y;\alpha)\,dx\,dy$$

where $2a$ is size of the pixel, I is beam intensity at a point (x, y) in a cross-section perpendicular to beam axis, and $\alpha(z)$ is z-dependent spot-size parameter. Using the above equation, $P(x_o,\alpha)$ vs. x_o can be simulated for different values of $\alpha(z)$ for a known intensity profile I. A comparison of $P(x_o,\alpha)$ vs x_o with counts vs. x_o, for a marked pixel, can result in the spot-size parameter $\alpha(z)$.

Fig. L.7.1 shows a schematic of the experimental setup of scanning pixel technique. A He-Ne laser beam was used to generate Gaussian and Bessel beams of spot-size comparable or smaller than the size of a CCD-pixel. To measure the spot-size with the proposed scanning pixel technique, a CCD

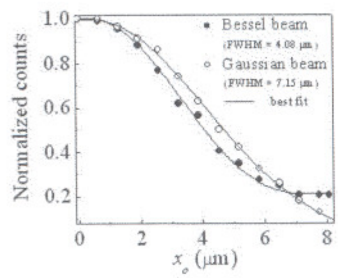

Fig L.7.2 Variation in counts (normalized) on a pixel with xo.

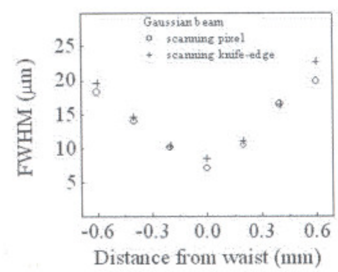

Fig L.7.3. Comparison of scanning pixel and scanning knife-edge results on a Gaussian beam.

camera (6.45 μm x 6.45 μm pixel-size) mounted on a PZT-controlled translation stage was used. After positioning a pixel at the beam centre, its position (x_o) with respect to beam center was varied by translating the CCD transverse to the beam axis. The counts on this pixel were recorded for each (x_o) to obtain number of counts vs. x_o graph for the pixel. Fig. L.7.2 shows this data (normalized) measured for Bessel and Gaussian beams. The continuous curve shows the best-fit $P(x_o,\alpha)$, for $1/\alpha$ to be 1.8 μm and 6.1 μm for Bessel ($J_o^2(\alpha\rho)$) and Gaussian ($e^{-2\alpha^2\rho^2}$) intensity profiles respectively, where $\rho^2=x^2+y^2$. The corresponding FWHM values are 4.08 μm and 7.15 μm respectively. Efforts to measure the central spot-size of this Bessel beam using well-known knife-edge technique failed due to a small variation in signal over a large signal obtained due to side rings. Finally, a comparison of scanning pixel and scanning knife-edge measurements was made on a Gaussian beam (Fig. L.7.3). A very close agreement in results from these two methods proved that scanning pixel technique is reliable.

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