Near IR Laser Beam Analyzing System

Mohamed S.Ahmed* & **Muna S. Yousif****

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Abstract
A simple and reliable laser beam analyzing system has been constructed and utilized for analyzing NIR laser beams. The system uses a CCD camera of 488×380 pixels (12 m pixel size) CCD chip, which is interfaced with a PC computer. Computer programs, utilizing facilities provided by MATLAB software, have been developed for analyzing laser beams and display them in 2D and 3D configurations. The obtained good quality laser beam images together with the efficient developed software have made the system a reliable profiler.

Keywords: Laser profiler, Laser analyzer.

منظومة تحليل حزمة ليزرية تحت الحمراء القريبة

الخلاصة
تم بناء منظومة تحليل حزم ليزرية موثوق بها واستخدامها في تحليل حزم ليزرية في المنطقة تحت الحمراء القريبة 0 تستخدم هذه المنظومة كاميرة CCD ذات شريحة 388*488 بكسل (حجم البكسل الواحد 12 مايكرون)متصلة بحاسوب 0 تم بناء وتطوير برامج حاسوبية خاصة بتحليل الحزم الليزرية وعرض النتائج بأشكال ذات بعدين وثلاثة أبعاد مستثمرة للتسهيلات التي يقدمها البرنامج MATLAB0 أن صور الحزم الليزرية المستحصلة ذات النوعية الجيدة جنب الى جنب مع البرامج الحاسوبية الكفوءة تجعل من المنظومة منظومة تحليل معتمدة.

Introduction

There are many applications of lasers, in which the beam profile is of critical importance. When the beam profile is important, it is usually necessary to be measured to insure that the proper profile exists. For some lasers and applications this may only be necessary during the design or fabrication stage of the laser. In other cases, it is necessary to monitor the laser profile continuously during the laser operation.

In general, the analysis of laser beam is based on energy measurement, the intensity distribution of the laser beam, beam divergence, waist parameter, number of modes... etc. Usually, the above parameters were measured individually by using separate settings. Laser beam profilers adopting various recording and analyzing techniques have been reported.[1-4]

Certain CCD cameras are usually used to provide simultaneous whole two-dimensional laser beam measurement for visible and near infrared (NIR) wavelengths. Examples are (i) the work of Martin F. and Willman J.G.[5] in which video graphic systems using two –dimensional CCD arrays , serve as a real time laboratory diagnostic tools for laser development , are presented (ii) and the work of Frank J.D [6] in which two instruments using conventional aperture technique and an instrument diode matrix array are described. The availability of high resolution CCD chips nowadays encourages designers and researchers to incorporate them in their laser profilers.[7-9]

*Applied Sciences Dept , University of Technology / Baghdad
** Education College, Koya University

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

The present work aims to design and construct a laser beam profiler based on CCD camera that can be assembled and utilized fairly easily in laboratories. The work is concentrated on analyzing NIR continuous and quasi-continuous laser beams. Computer programs have been developed for analyzing laser beams and display them in 2D and 3D configurations.

System Description

This work describes the design and performance of a video graphics system that gives a two-dimensional image and an energy profile of the output laser on a continuous wave (or quasi-continuous) basis.

The system under consideration is a CCD- based beam diagnostic system creates a pseudocolor representation of the intensity distribution for the full beam. A standard ½" CCD video camera of 488×380 pixels (12 m pixel size) and spectral range from 0.4 to 1.1 m CCD chip is incorporated into the system. The spectral range of the camera is thus adequate for carrying out He-Ne laser, laser diode and Nd: YAG laser intensity profile analyses and measurements.

The system includes analog-to-digital converter from which digital data is transferred to a computer memory of a microprocessor, the microprocessor coupled to the computer memory for retrieving and processing data. A display unit for determining the total energy, divergence and position of an applied laser beam, and optical accessories such as attenuators, spectral filters, holders,. …etc. have been employed to assure a suitable imaging arrangement.

System arrangement

An arrangement of the equipment under consideration is shown in the block diagram Fig. (1). Laser beam under investigation is allowed to pass through a beam optics unit for attenuation, optical filtering and/or modulation purposes before it is projected on a transmission screen. A CCD camera of an appropriate objective optics records the laser spot formed at the screen and transmits it to a computer system for image analysis and processing.

System Software

For the purpose of evaluating and determining the laser beam characteristics computer programs have been developed. A dialogue is established between the user and the computer, enabling the user to follow the required imaging and measuring procedure. The software utilizes the following formulae. The ideal laser beam profile is described by a Gaussian function. The mathematical representation of this function is given in the form of a sequence of Gaussians: [10]

$$d_a(x) = \sqrt{\frac{a}{p}}\, e^{-ax^2} \qquad \text{….. (1)}$$

where a=1,2,3,…

The Fourier transform of this function is a Gaussian of the form

$$F(k_x) = e^{-k_x^2/4a} \qquad \text{….. (2)}$$

The standard deviations for the two functions are

$$\left.\begin{aligned} d_x &= 1/\sqrt{2a} \\ and & \\ d_k &= \sqrt{2a} \end{aligned}\right\} \qquad \text{….. (3)}$$

From many different approaches that can be followed in determining the beam divergence, the most common and acceptable one that depends on the (1/e2) points in measuring the beam diameter is used here[11-13]. The full angle divergence is calculated by using the following relation, see Fig. (2-b).

$$q_{mrad} = \left(\frac{D_2 - D_1}{Z_2 - Z_1}\right) \times 1000 \qquad \text{….. (4)}$$

where

D1 is the (1/e2) points beam diameter at distance Z1,

D2 is the (1/e2) points beam diameter at distance Z2, (Z2>Z1),

And D's (which will be determined by the computer) and Z's are measured in the same appropriate units.

Fig.(2-a) illustrates the beam divergence measurement procedure that have been followed here, where the laser cross section (laser spot) is projected on a receiving transmission screen and imaged at different distances Z1 and Z2 (where Z2>Z1) from the laser source. For displaying laser spots in 2D and 3D configurations MATLAB software has been utilized.

Laser Beam Analysis

The system under consideration was used to analyze visible and near infrared continuous wave lasers. High repetition rate NIR pulsed diode lasers were also examined. In all cases, concentration was made on revealing detailed intensity information across laser beams. Examples are given. A continuous wave 30mW NIR (λ=0.83nm) diode laser was imaged and analyzed as shown in Fig. 3. A 30mW NIR diode pumped laser of (=1.062 m) and repetition rate of 20kHz with pulse width of 2ns was imaged and analyzed as illustrated in Fig. 4. In both figures it is seen that the intensity profiles of the recorded lasers are not perfect smooth Gaussians; a central dip is shown in the former and spikes are occurred in the latter. These peculiar profiles have to be taken into account in certain applications where Gaussian intensity distributions are required.

Conclusions

The laser beam analyzing system designed and constructed in this paper has been used to analyze visible and NIR laser beams. Results have indicated the successfulness of the profiler under investigation in displaying proper laser images and the associated 2D and 3D configurations. It is worthwhile to mention here that despite the use of a CCD camera that employs conventional CCD chip type of spectral range 0.4 to 1.1 m of peak responsively at =0.57 m, adequate performance over the NIR range has been experienced. CCD cameras of high resolution chips may be used for more improved results.

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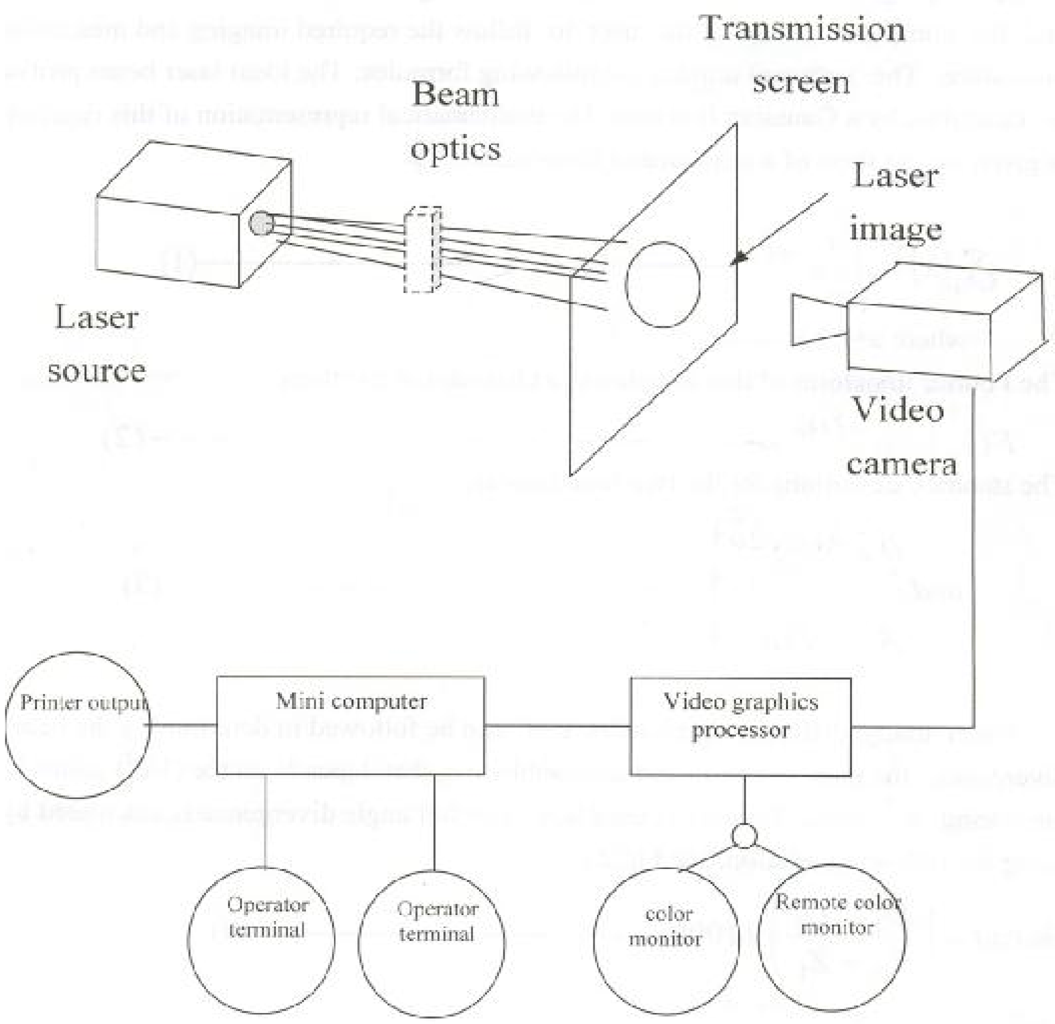

Figure (1) The laser beam profile block diagram

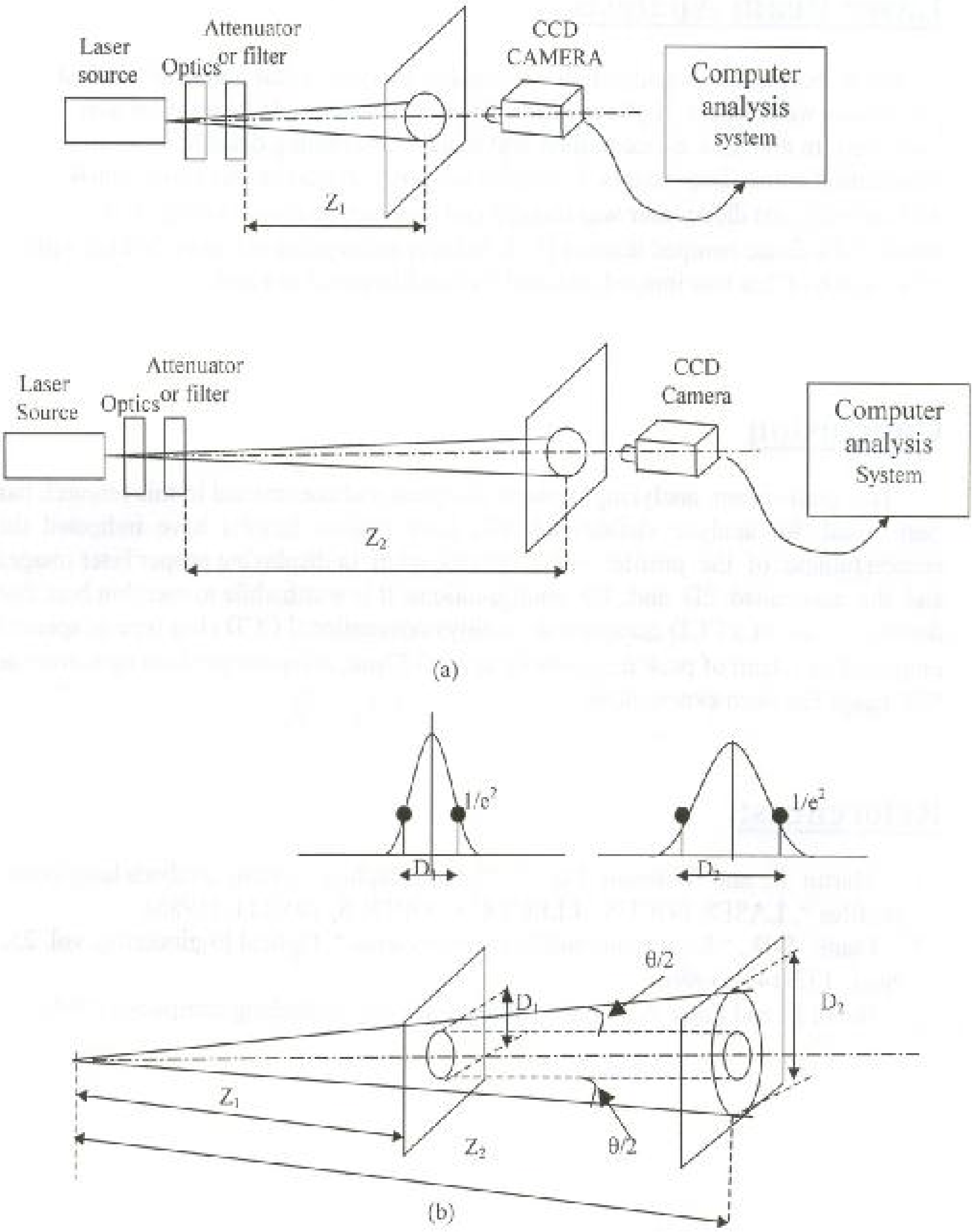

Figure (2) An illustration of the beam divergence measurement: (a) imaging setup, (b) beam divergence geometrical diagram.

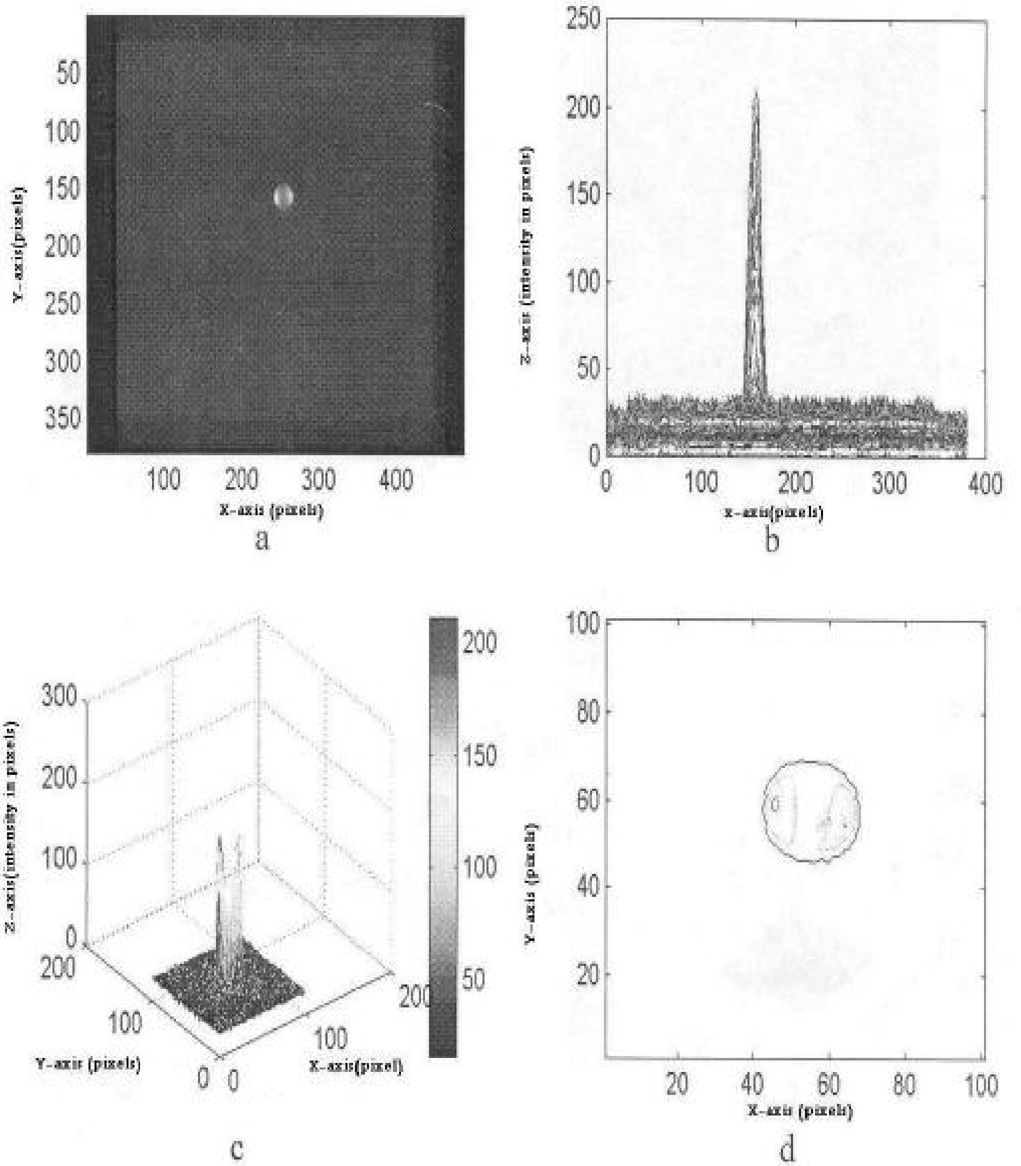

Figure (3) Analysis of NIR CW diode laser of λ=0.83μm and p=30mW: (a) image of the laser beam, (b) 2D- intensity distribution along x-axis, (c) 3D- intensity distribution, (d) laser spot contour.

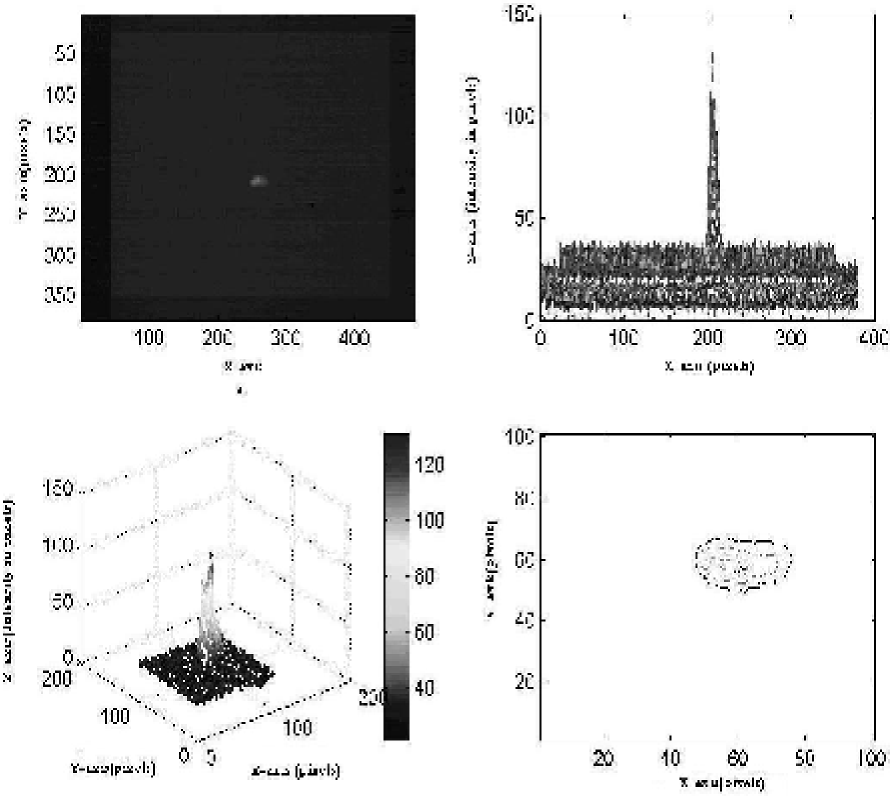

Figure (4) . Analysis of a diode pulsed laser of λ=1.062µm:(a) image of the laser beam, (b) 2D-intensity distribution along x-axis,(c)3D-intensity distribution, (d) laser spot contour.