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Stand off Measurement Technique of Small Signal using Lock-in Amplifier

Satyender Kumar[1,2], N R Das[2], A K Srivastava[2]
[1]*Mewar University, Deptt of Physics, Chittorgarh, Rajasthan, India*
[2]*Laser Science & Technology Centre, DRDO, Delhi, India*

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ABSTRACT: This paper presents the small signal measurement technique of CO_2 Gas Dynamic Laser to avoid heavy noise in the environment or circuit. Different type of experiments in the laboratory requires an accurate and precise measurement of a slowly varying, extremely small voltage. Optical gain signal is the example of this type of signal measured here. Gain measurement involves the ratio metric technique which transform the optical signal to electrical by pyro-detector and interfacing the signal through Lock-in Amplifier. The signal in lock-in amplifier is locked and processed through GPIB card in the computer. The data was analyzed through labview software. Lock-in detection is an important instrument and a powerful technique to recover such low optical signal, even in the presence of noise whose magnitude is several times greater than the signal itself. A versatile, low-cost digital lock-in analyzer with software has been employed. No specialized hardware is required except a general-purpose data acquisition board, where the detector has sensitivity of order of nano Volt. All signals processing takes place on the computer by displaying the wavefront of intensity vs. time. Finally measured gain value of 0.29/m through software successfully.

I. INTRODUCTION

The small signal gain is an extremely important figure of merit for gas laser devices such as Gas Dynamic Laser (GDL). It is also a direct measurement of the population inversion. Higher the small signal gain, higher is the population inversion and hence the higher output power of laser. In order to maximize the output power of a laser with given dimensions, the small signal gain should be normalized. The small signal gain of GDL CO_2 laser depends on gas mixture ratio, temperature of the reservior gas, distance from the throat, the size of area of the nozzles, optical design of the laser cavity, pressure etc. With higher value of small signal gain, it is easier to achieve laser action in a medium. The measurement evaluation of the small signal gain coefficient is based on measuring of the probe CO_2 laser intensity relative increment when it is going through the active medium of CO_2 GDL. Hence, the small signal gain coefficient (g_0) of a laser gain medium may be expressed as:

$$g_0 = \frac{1}{L} \ln \frac{I}{I_0} \qquad (1)$$

Where,

- L = Length of the gain medium.
- I_0 = the intensity of probe laser.
- I = Intensity of probe beam after travel through the active medium.

Two digital lock-in Amplifiers (LIA has been impelemented. It gives the good result of measurement on the basis of ratio and measuring two signals simultaneously. It is interfaced with two Lock in Amplifiers through signal cable using NI PCI-GPIB Card, NI-488.2 includes TNT4882C based IEEE 488.2 board for the PCI bus (fig. 1) and double-shielded GPIB cable, with Driver Software NI-488.2 for SR830 and programmed using software in Lab View. The block diagram of program for a Lock-In Detector is shown in fig.2 and front panel window is shown in fig. 3. We used the Lock in amplifier to measure the voltage signal using the frequency based pyro detector which is converting the CO_2 laser power in the voltage signal at known frequency of 30 Hz created by a chopper. This versatile device detects a small signal (less than a microvolt).

It is difficult to measure such a small signal for several reasons. Measurement suffers from offset and drift – several effects (common-mode error, thermoelectric offsets, internal offsets, and rectification of noise) which will add or subtract to the signal level and these offsets will vary with temperature and time. These errors may be mitigated but not eliminated. The laser power before chopping is 200 mW and the detector max threshold was 2 W. This power will be converted into voltage low signal of order of µV. This means the voltage to be measured of the order of micro volt. It is also unconvincing to make zeroing the amplifier. An external chopper frequency of 30 Hz is employed to detect the signal on the basis of known frequency. A lock-in detector takes a periodic reference signal and a noisy input signal and uses a pyro detector to extract only that part of the output signal whose frequency and phase are matched with the reference i.e. the chopper frequency which is a known frequency. Since the lasing process takes place only 2-3 sec while measurement has to complete within this stipulated time frame. Also, GDL firing process is controlled remotely, because high pressure and temperature are involved, so only stand off dtection of gain measurement of the system is possible.

II. MEASUREMENT TECHNIQUE

Detect the Lock-in-Amplifier through VISA resource Name I/O and initialize the address GPIB:8 and 9 on front Panel of the lock in amplifiers. Select the GPIB 8 in First Visa Resource and select the GPIB 9 in the Second Visa resource Name. Then Select the most important parameter Internal/External reference frequency. Internal frequency (1000Hz) but selects only External Frequency given by Chopper to both the lock in amplifiers. The other most important parameter is the length of the resonator cavity (Input signal L) is to be given before the running of experiment. It is displayed on the front panel.

Fig.:1 NI PCI-GPIB Card, NI-488.2 TNT4882C based IEEE 488.2 board for the PCI bus

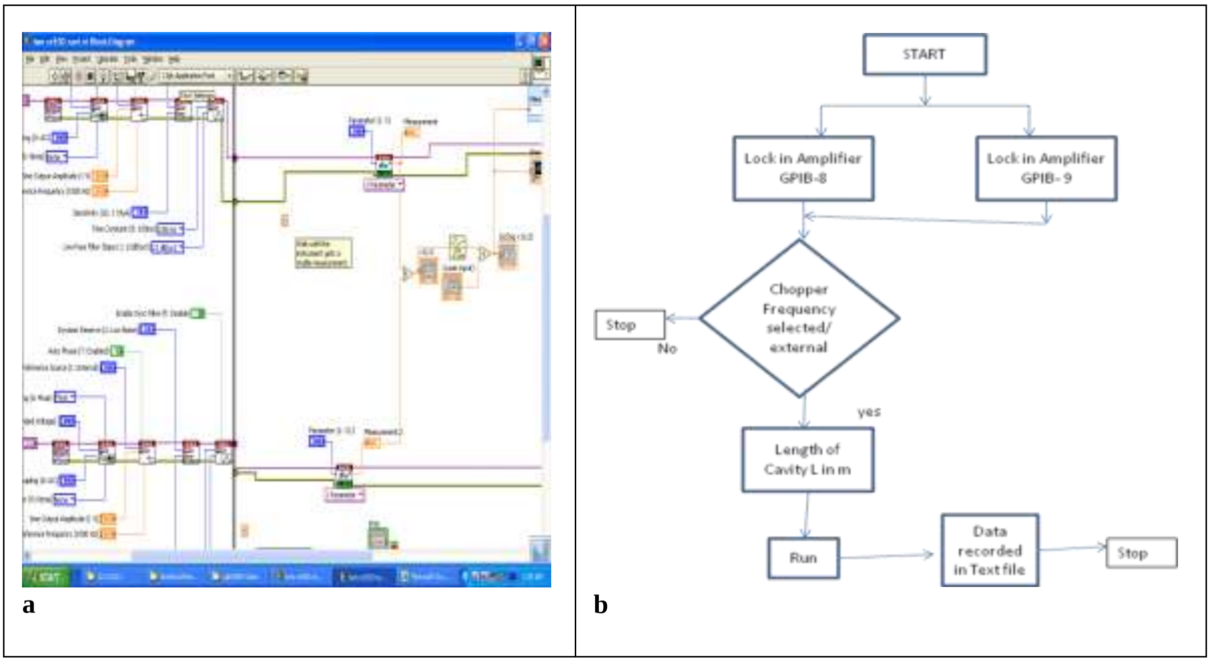

Figure: 2 Block Diagram for programme

Through internal software programming both the signals from lock in amplifiers were recorded on ratio metric basis. These values (initial and final) of signal are displayed on the front panel. Gain is measured according to equation (1). This signal is recorded to measurement file and also displayed on front panel in the form of time vs. gain. Implementation of Lock in amplifier (LIA) performs lock-in detection completely through software. A general-purpose data acquisition (DAQ) card used to read the time-varying signal, noise and all, into memory. The input waveform passes through all the subsequent stages of lock- in detection as a digital record which filters the noise. The program is written in LabView, version 9.0. LabView is a visual high-level programming language for data acquisition, analysis, and simulation. “Coding” a LabView program involves laying out a data flow diagram. For example, the Fig.2(a, b) shows the section of our LIA program in which the lock-in is performed.

The only hardware required is a high-gain low noise general-purpose DAQ GPIB card National Instruments GPIB multifunction I/O board is used having analog input applied frequency and voltage and one analog output, which worked excellently, for this application. The program begins by initializing the DAQ card. It sets the acquisition parameters, such as the sampling rate and the voltage range of each signal.

III. RESULTS

It is an optical system. In this system the applied signal is modulated mechanically by chopping the laser light beam at fixed frequency. So, we have used a frequency-locked loop to synchronize the reference with the applied signal. The DAQ card generates this waveform at an output which yields the reference frequency of 30 Hz. The DAQ board continuously generates the waveform, no interaction with the computer is necessary at the time of experiment. So, the stand off detection is possible.

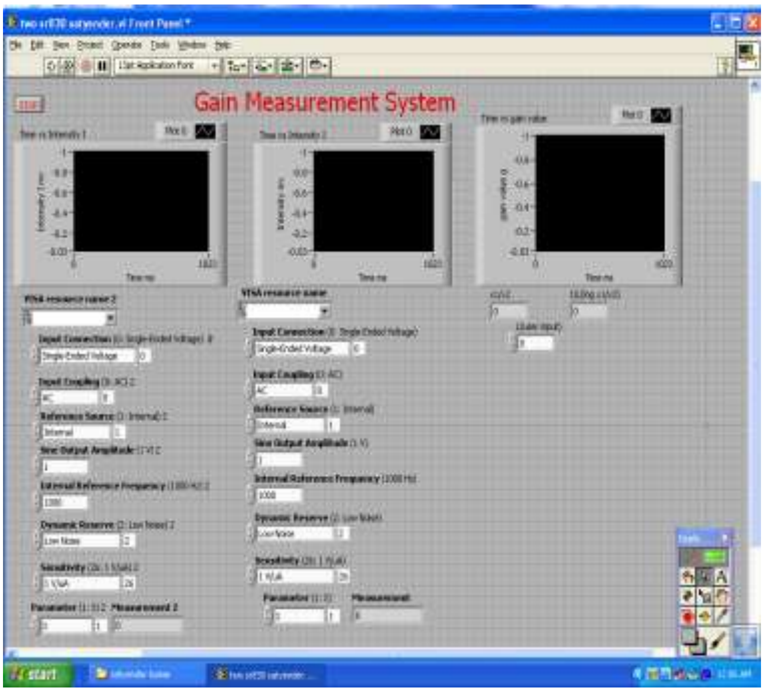

Figure: 3 Front panel window of software

The program also sets the data acquisition parameters and begins acquisition (fig-3). The board continuously samples its inputs at the specified rate of 100 ms and stores the values in a temporary buffer. The result is a waveform containing the gain value sampled at 30 Hz. The program records gain value with time to text file continuously. This process continues until the user requests the program to stop; at this point the program stops the output generation and the acquisition, performs housekeeping such as closing its data file, and exits. We have recorded the gain coefficient 0.29/m through software successfully.

IV. CONCLUSION

Gain measurement of high power laser is a potential technique which not only tells the health of lasing medium but also enables system power extraction capabilities. Morever stand-off detection of gain measurement is very effective where high pressure and temperature is involved and maintaing distance between system and human interface or command control. The lock-in amplifier is an important and versatile instrument. At the same time, Lab View has powerful simulation capabilities. It can not only implement the Lock in amplifier but also can simulate the entire experiment. It can be used to analyze the complete data, record the data and finally generate the report.

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