MASTER SLAVE TOPOLOGY BASED, REMOTELY OPERATED, PRECISION X-RAY BEAM PROFILER AND PLACEMENT SYSTEM FOR HIGH PRESSURE PHYSICS EXPERIMENT AT INDUS-2 BEAM LINE

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Abstract

RRCAT has commissioned a beam-line on Indus-2 synchrotron facility for carrying out Angle Dispersive X-ray Diffraction Measurement. A typical high pressure measurement is carried out by placing the sample in the Diamond Anvil Cell (DAC) with the sample located in a region of beam diameter within 50-100 µm. The X-Ray beam has to pass through the DAC to ensure maximum illumination of the sample with the X-Rays. An X-Y beam scanner/locater cum placement system is developed, which scans an area of 10 x 10 mm^2 with resolution of 10 to 100 µm in rough scan mode and fine scans selected area with programmable resolution of 2.5 to 25 µm. The scanner acts as slave to the PC in which master GUI grabs the data on serial port and plots the image of X-ray beam. It also analyses and detects the coordinate with maximum intensity. Thus the DAC can be placed at the desired location with an accuracy of 2.5µm anywhere within 10 x 10 mm^2, for performing experiment. Developed system takes only ~5 minutes to search the beam and a few seconds to place DAC at any the desired location within the scanned area.

INTRODUCTION

RRCAT has commissioned beam-line (BL-12) on Indus-2 synchrotron facility to carry out Angle Dispersive X-ray Diffraction (ADXRD) measurements. Since its commissioning, this beam-line has been used by various researchers, however, for its wider utilization; it is upgraded to perform measurements at high pressures using Angle Dispersive geometry. High pressure XRD measurements are extremely important to determine the structural properties of materials under extreme condition and provide information about the bulk modulus, stable phases etc. It is carried out by placing the sample in the Diamond Anvil Cell (DAC) that has a very small sample volume with a cross-sectional circular opening area of ~150 micros. Alignment of the incoming X-Ray beam from the beam-line with sample in DAC to ensure maximum illumination of the sample is thus a challenging task. Further, as the X-Rays are ionizing radiations and the exposure to the user needs to be essentially avoided, the alignment needs to be carried out in a shielded environment using a remote controlled system. To accomplish the above tasks, a master slave topology based remotely operated precision beam locator cum placement system and interactive control software to measure beam size was developed.

The DAC is mounted on a two axes translation stage, with motion in a plane perpendicular to the X-Ray, and an X-ray sensitive detector is placed behind the cell. The software guides the DAC through a matrix of user selected points and the detector, gives the X-Ray intensity through the DAC as a function of its X & Y position. These data are presented in image format, which can be displayed in various shades of color. The optimum position of the DAC is determined as the co-ordinates where the transmission of X-Rays through the DAC is the maximum.

SYSTEM DESIGN PHILOSOPHY

- ADXRD beam line of Indus-2 has been used by various researchers may or may not be software conversant. Keeping this point in mind, GUI based robust software have been designed and developed, which is self-explanatory and has capability to guide even a beginner. To fulfill this, in software design, elaborate error handing has been incorporated.

- The instrument uses indigenous components like XY motorized translation stages manufactured in India and its fast driver and controller have been developed in-house at RRCAT.

- Keeping current and future software trend in mind it was decided that software must operate on future Windows platform (64 bit) instead of currently used Win XP.

SOFTWARE

The GUI based software is named **Lakshya,** functions as master and is developed using Vb.Net. XY translation stage control and data acquisition unit based on micro controller and its software is developed in assembly language, which functions as a slave unit of **Lakshya**. All the settings of XY translation stage and data acquisition module are done in master's GUI and final user approved settings are only transmitted to slave for execution. Current software uses 10 x 10 mm² area to locate x-ray beam. Keeping future need and different applications in

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mind software is developed in such a way that higher scan size and data resolution (8 to 16 bits) can be adopted.
Figure 1 shows main window of Main window of **Lakshya**. The scanned image size depends on selected resolution i.e. Image Width & Height = 10000/Selected resolution.

Software salient features

(1) Rough scan: In this mode, an area of 10 x 10 mm² with selectable resolution of 10 to 100 μm is carried out. This provides the tentative X-ray beam location in 2-D format. It takes ~ only 5 to 6 minutes for a rough scan at a scanning resolution of 50 μm.
(2) Fine scan: The area is selected from rough scanned image with programmable resolution from 2.5 to 10 μm in steps of 2.5 μm. This provides accurate 2-D map of X-ray beam. Beam size can be measured manually selecting coordinates or automatically. It also provides accurate beam profile.
(3) The DAC / detector can be placed on desired position within accuracy of ≥ 2.5 μm. The position point is picked by a mouse click from scanned x-ray beam image.
(4) After placement at the desired location the Si photodiode detector provides the beam intensity at set position which provides long term stability of the beam.
(5) Programmable S/N enhancement facility has been incorporated to seek weak signal.

EMBEDDED TRILOCHAAN IN LAKSHYA

Lakshya has been integrated with existing Trilochan software for image processing and measurement facilities. It directly provides 2-D Intensity profile and 3-D view in different viewing angles also directly measures X-ray beam size. To reduce noise, facility of programmable low pass filter and median filtering can be used which are shown in the Figure 2.

SLAVE UNIT HARDWARE

The scanner is controlled by an indigenously developed 80C552 microcontroller based CPU card having internal 10-bit ADC, ports for motor control, front panel display and keypad connections. Scanning is performed at 2.5 μ / step in both X and Y direction. To reduce the overall scan time, high speed stepper motors are used, which are controlled by an indigenously developed universal control cum driver card interfaced to CPU. Provision of optical limit switches is made for safety of the system in both directions.

Further, to improve reliability of data transfer on serial link to avoid EMI, an optical fiber based serial interface have been incorporated which provides reliable data transfer 57.6 kbps. Pre-amplifier for detector head (Si photodiode AXUV-100) uses the current to voltage converter having trans-impedance of 1 GΩ and dynamic range of 120 dB. Input pins are guarded to avoid the leakage. Precision zeroing circuit is also added to compensate for background signal from detector. The unit has provision for digitally programmable gain selection of 1, 10, 100 and 1000 from master PC and an averaging based selective signal to noise ratio enhancement facility has been incorporated to capture weak signal.

PERFORMANCE AND RESULTS

The data was taken, at 17 keV photon energy, on the image plate with an acquisition time of about 20 minutes. The samples were placed inside a DAC with a gasket diameter of about 150 microns. No significant gasket peaks are observed because the precision x-y scanner stage ensured that the X-Ray beam passes exactly through the centre of the DAC. Figure 3 shows the diffraction patterns of LaB_6 as a function of pressure. The absence of the gasket peaks and the shift of the Au peaks with pressure are clearly seen. The cubic phase peaks of the LaB_6 are highlighted in the data.

CONCLUSION

We have designed and deployed the Lakshya system for Indus-2, BL-12, RRCAT to precisely align the incoming X-ray beam on the DAC for perform high pressure measurements. Developed system takes only ~5 minutes to search the beam and takes only few seconds to place DAC at any the desired location within the scanned area.

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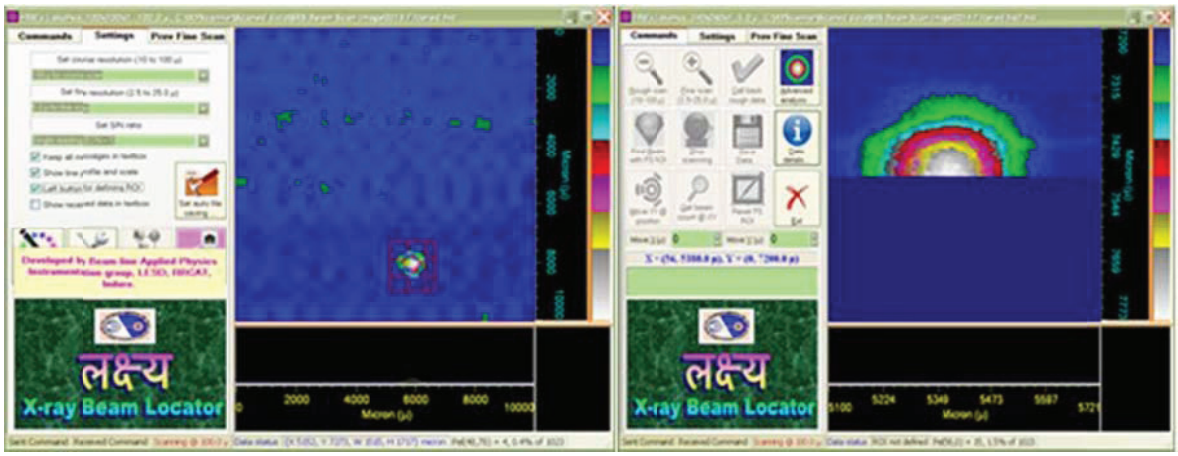

Figure 1: Main window of LAKSHYA shows marked rough scan image and fine scan in progress.

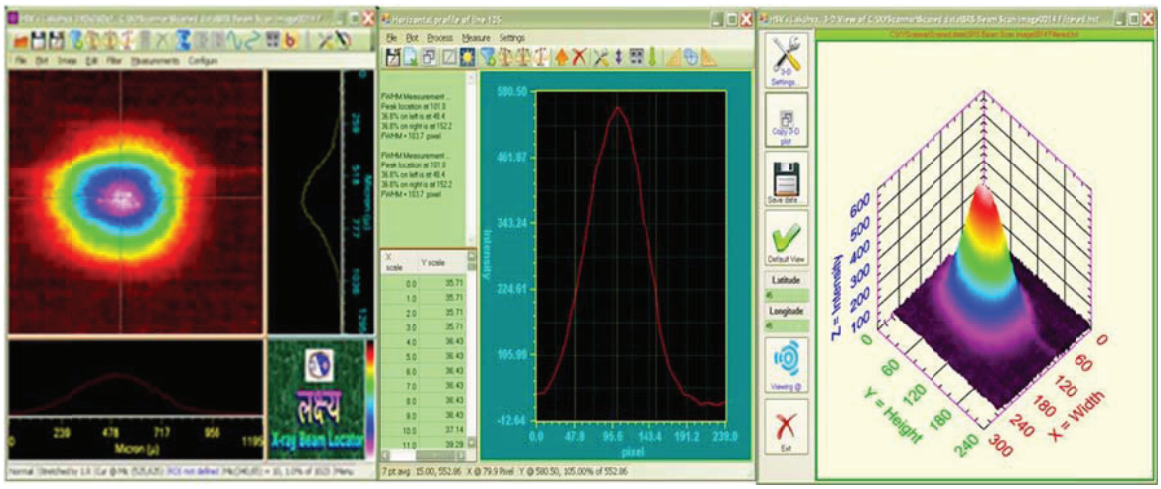

Figure 2: Embedded Trilochan in Lakshya for processing and measurements of acquired scanned beam.

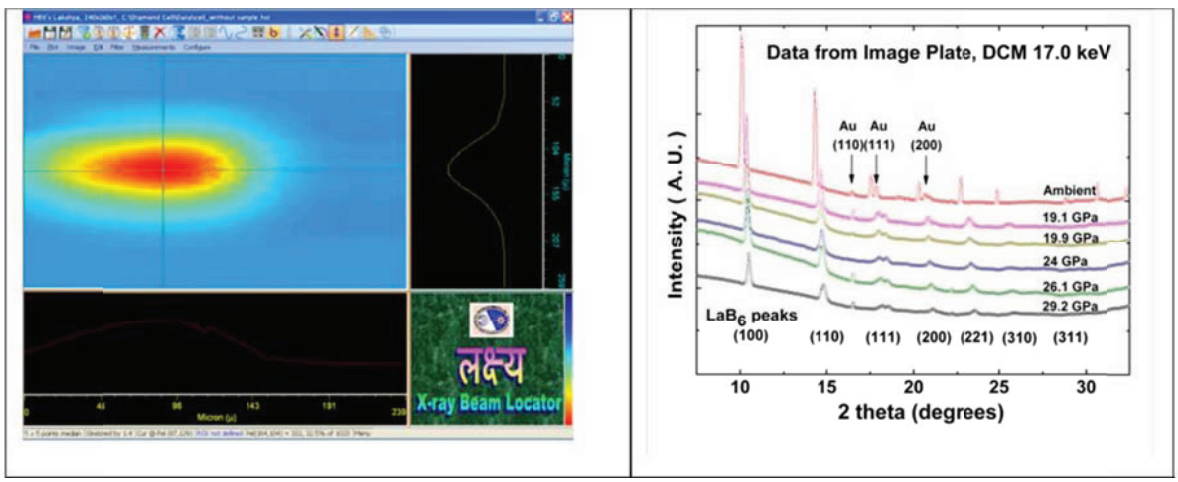

Figure 3: X-ray beam 2-D map and data for sample LaB6 at different pressure.

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