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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Aim

• To measure Angle Dispersive X-Ray Diffraction (ADXRD) at High pressure. It is extremely important to determine the structural properties of materials under extreme condition.

• Beamline BL-12 of Indus-2, for its wider utilization, is being upgraded to perform high pressure experiments in the ADXRD geometry.

• Use DAC to generate high pressure (~10^6 bar).

• To align repeatedly and mount precisely the Diamond Anvil Cell (DAC) for the experiments.
Challenges

- X-Rays being an ionizing radiations, exposure to the user needs to be strictly avoided
- To locate precisely $\sim 100 \ \mu$ wide incoming X-ray beam in $10,000 \times 10,000 \ \mu^2$ ($10 \times 10 \ \text{mm}^2$) area
- After locating the beam, placement of the DAC ($300 \ \mu$ opening) at the centre of the beam with accuracy of $\sim 2.5 \ \mu$
- The alignment needs to be carried out in a shielded environment using a remote controlled system
Development

- A remotely operated precision beam locator cum placement system **Lakshya** based on a master slave topology has been developed.

- Instrument uses all indigenous and low cost components i.e. XY motorized translation stage (TS), its driver, controller, Plastic serial link and software have been developed in-house at RRCAT.

- Ta (tantalum) orifice is made by drilling a 100 micron hole in a 400 µ thick Ta sheet, its thickness ensures complete absorption of the highest photon energy from the beamline (25 keV).
Experimental Setup

Schematic of the high pressure experiment setup
Experimental Setup cont..

• DAC is mounted on a two axes translation stage (TS) with X-ray sensitive detector placed behind it

• TS motion in a plane perpendicular to the X-Ray beam

• Software guides the DAC to scan selected region

• The detector, gives the X-Ray intensity through the DAC as a function of X & Y position

• Data is presented in image format

• Optimum position of the DAC is determined as the co-ordinates where the transmission of X-Rays through the DAC is the maximum
Lakshya, लक्ष्य
Master software

- ADXRD beam line (BL-12) is used by various external researchers also, **may not be software conversant**

- GUI based robust software have been developed, which is self explanatory and has self guiding capability. Extended error handling incorporated

- Elaborate Image Processing software **TRILOCHAN** is a part of Lakshya to carry further measurements
Lakshya, Scanning …

• **Rough scan**
  
  – Scans 10,000 x 10,000 $\mu^2$ with selectable resolution (10 to 100 $\mu$). Which provides the tentative X-ray beam position in 2-D format

  – Takes ~ only 5 to 6 minutes for a rough scan at a scanning resolution of 25 $\mu$

• **Fine scan**

  – The area is selected from rough scanned image. Scanning with programmable resolution from 2.5 to 10 $\mu$ in steps of 2.5 $\mu$

  – Provides accurate 2-D map of X-ray beam
Lakshya, SW Features

• After scanning, the DAC / detector can be placed on desired position

• Mouse movement provides beam intensity at cursor position

• DAC placement location is picked by a mouse click from scanned x-ray beam image (No range exceed message)

• After placement of DAC at the desired location as a feedback, it provides the X-ray beam intensity
Lakshya, SW features cont..

- Intensity profile measurement in horizontal, vertical direction
- Direct Measurements of beam size
- Selectable pseudo color shades & schemes
- Low pass filter in X, Y or XY direction for noise reduction
- Median filtering for removing isolated noise with minimum blurring
- On-line color stretching provides full-scale color resolution
- Viewing 3-D image at different viewing angle
Lakshya, Rough Scan

Rough scan @ 100 micron. Image shows SRS beam clearly. The defined ROI is further fine scanned to know exact position of beam.
Lakshya Fine Scanning

Fine scanning in progress.
Embedded **Trilochan** in Lakshya
Color shades and pseudo color

Beam in 256 Shades.

Beam in 256 pseudo colors.
Removing Noise

- Removes isolated noise without blurring
- Data rearranged, No new value generated

Image with isolated noise

3x3 median filtered
3D View of X-ray Beam using Lakshya
Rough Scan

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Fixed Scan Size</th>
<th>Resolution</th>
<th>Image Size</th>
<th>Scan Time</th>
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<td>16000 S</td>
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<td>“</td>
<td>100 μ</td>
<td>100 x 100</td>
<td>25 S</td>
</tr>
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</table>

From Master: aSC + No. of data in line (4) + No. of lines (4) + Direction (1) + ADC S/N (1);

- Reply from slave: [= Line no. (4), No. of data points (4) + dd, dd, dd, …… dd + Checksum (6) + FSOVR]
- All reply from μC is received as an EVENT
Fine scan

From Master: aFC + Start position (4) + End position (4) + No. of data in line (4) + No. of lines (4) + Direction (1) + ADC S/N (1);

Reply from slave: [= Line no. (4), No. of data points (4) + dd, dd, dd, ... dd + checksum (6) + FSOVR]

Go to X,Y

From Master: aXY + X Position (4) + Y Position (4);

Reply from slave: [= X Position Y Position, MOVED]
All in one type 80c552 based CPU card
16 Ch TTL Digital inputs / outputs
8 Ch analog inputs (10 bit), 16K EPROM, 32K RAM

~ 150 such CPU Cards are being used in various DAE Units
Universal Stepper motor controller, can be used with any CPU for 4 - 8 wires motor
High speed data transfer (57,600 baud rate) optical serial link is used. No bit error observed even in a Giga bits of transmission. Developed at RRCAT, being used since 1994.
DAC mounted on an automated X-Y scanner controlled through Lakshya
Results: XRD Pattern of $\text{LaB}_6$ as a function of pressure

Measurements carried out on developed setup, using NIST standard $\text{LaB}_6$ powder as a function of pressure. Au powder was used for the calibration of the pressure inside the cell.
Thank You