# High Dynamic Range Beam Imaging Measurements with a Digital Micro-mirror Device

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## ABSTRACT

A particular challenge in transverse beam profile monitoring at synchrotron light sources is the detection of beam halo particles. This is due to the high intensity of the synchrotron light coming from the core of the beam overshadowing the much weaker signal coming from halo particles.

Changes in beam halo are usually associated with emittance growth, particle losses and even damage to accelerator components. Thus, it is very important to have a method in place which allows non-invasive, high dynamic range measurements of full profile, including the halo.

Such a method is presented in this contribution. Experiments were carried out at Diamond Light Source in the UK, where the visible component of the synchrotron radiation was imaged onto a digital micromirror device (DMD). This allowed the DMD to serve as an optical mask to block the light coming from the beam core, enabling measurement of the halo. A dynamic range (DR) of ~10E5 was successfully demonstrated. The setup and monitor details will be presented, along a detailed analysis of all data and plans for future studies.

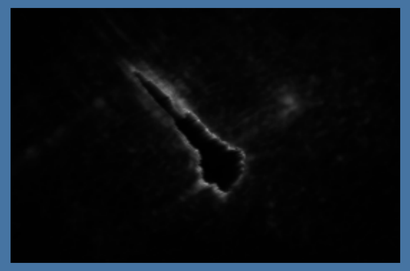

Figure shows masked core of the beam using DMD

## CONTACT

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## INTRODUCTION

A new imaging system has been developed at the Cockcroft Institute (CI). The system has been divided in three sub-systems to allow **easy installation**, **alignment**, and **focusing**.
The measurement at CI optics lab demonstrated that it is possible, with the new imaging system, to image object at ~6.5m distance using digital micro-mirror device (DMD).

The system was installed at Diamond Light Source (DLS) in the UK, where the visible component of the synchrotron radiation was imaged onto a DMD.

This allowed the DMD to serve as an optical mask to block the light coming from the beam core, enabling measurement of the halo**. A dynamic range (DR) of ~10E5 was successfully demonstrated; the dynamic range of the camera has been increased by two orders of magnitude**.

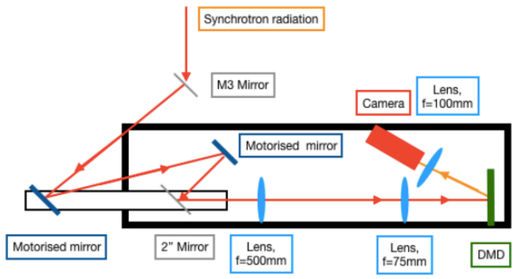


**Figure 1.** Schematics of the final imaging system set up at DLS.

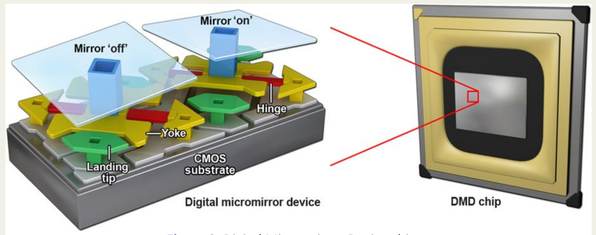


**Figure 2.** Digital Micro-mirror Device chip

## METHODS AND MATERIALS

Synchrotron light is extracted from the beamline using a half mirror, which is installed inside the beamline, to the M3 mirror, which is part of the pre-existing DLS VLE beamline. This mirror is rotated to guide the synchrotron light to the imaging system [Figure 1].

The imaging system has two motorized mirrors to enable easier remote alignment, and one fixed mirror, used to to maximise the limiting aperture of the system.

A DMD chipset [Figure 2] is made-up of several thousands of 7.5µm mirrors, so the image must be ~100 µm to provide enough resolvable points across the DMD surface. To resolve the image upon DMD, set of two lenses were used.

After successfully imaging the beam onto the camera via the DMD, the first mask was created.

The idea is as follows [Figure 4]:
**1. Initially image the beam at the minimum exposure time of the camera without a mask;**
**2. Create a binary mask at a certain intensity threshold;**
**3. Load this mask onto the DMD and take a new image at an increased exposure;**
**4. Repeat until the majority of mirrors on the DMD are switched off.**

**Figure 3.** Digital Micro-mirror Device

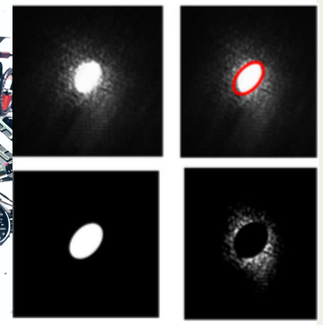

**Figure 4.** Mask formation using DMD [1]

## RESULTS

For this measurements, 10 masks were created.

The first image was taken of the beam without a mask. Camera exposure was set at 0.295ms, and intensity threshold at 45000. Final mask was created with exposure time of 2000ms and intensity threshold of 10000.

Figure 5 shows the combined plots of generated masks at different exposure times.

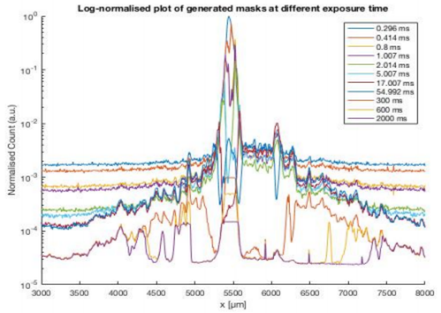


**Figure 5.** Horizontal plots at different exposure times combined together

By overlapping the horizontal scans for beam with no mask (0.296ms), and a few scans for beam with masks (0.8ms, 17.007ms, 54.992ms), the intensity drop in the beam core is clearly seen.

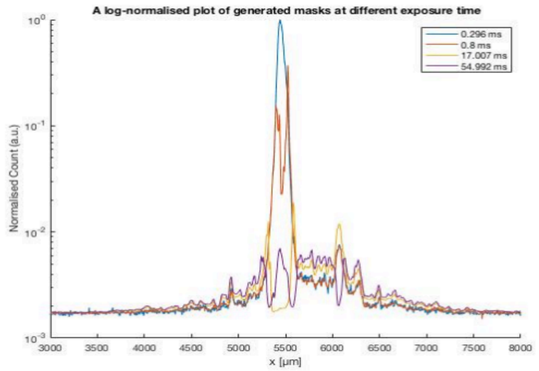


**Figure 6.** Horizontal overlapped plots for beam with and without mask

## CONCLUSIONS

Measurements have demonstrated the ability to achieve a dynamic range of ~10E5; extending the dynamic range of the camera by two orders of magnitude. By further development of the control and calibration software for the DMD, and taking background images each time a new mask is generated, HDR beam imaging measurements achieved here can be further improved.

With a minor modification, the same imaging system and software could be used for optical phase space mapping measurements. The measurements would provide information on transverse emittance values of the electron beam. Furthermore, measurements could also demonstrate that DMD can be used as Lyot stop.