KEK LUCX facility laser transport line alignment automatization

MOPP37

IBIC 2021

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Introduction

KEK LUCX facility* is a linear accelerator devoted to the beam instrumentation R&Ds for present and future accelerator systems and colliders. Parameters of electron beam generated by laser-driven photocathode-equipped gun are sensitive to laser wavelength, laser pulse intensity, duration (RMS), spot size (RMS) and spot position on the photocathode. Typically, tuning of such generation schema requires stable laser pulse generation and shaping, alignment of the laser transport line (LTL) and final focus optical system. Conventional diagnostics along LTL may include CCD cameras for position and profile tuning and monitoring including that at the virtual cathode position.

An approach to achieve laser spot size and position with the high level of stability and reproducibility on the photocathode is associated with the implementation of geometric optics based software protocol which allows for automatic- or semi-automatic alignment of entire LTL. This approach was developed and applied for KEK LUCX RF gun LTL alignment. It employs two CCD cameras**, motorized mirrors and optical telescope designed for laser pulse delivery to the photocathode.

This report shows the laser beam position and incidence angle influence on beam dynamics within KEK LUCX beamline, as well as LTL alignment algorithm mathematical model and commissioning plan.

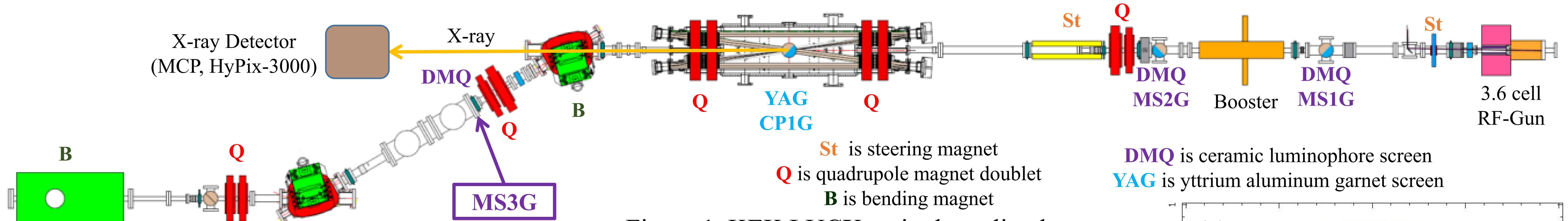

Figure 1. KEK LUCX entire beamline layout

All considerations are made in assumption of good alignment of entire LTL especially the necessary and sufficient conditions are that the full laser images can be seen at CCD's and periscope mirrors are well aligned.

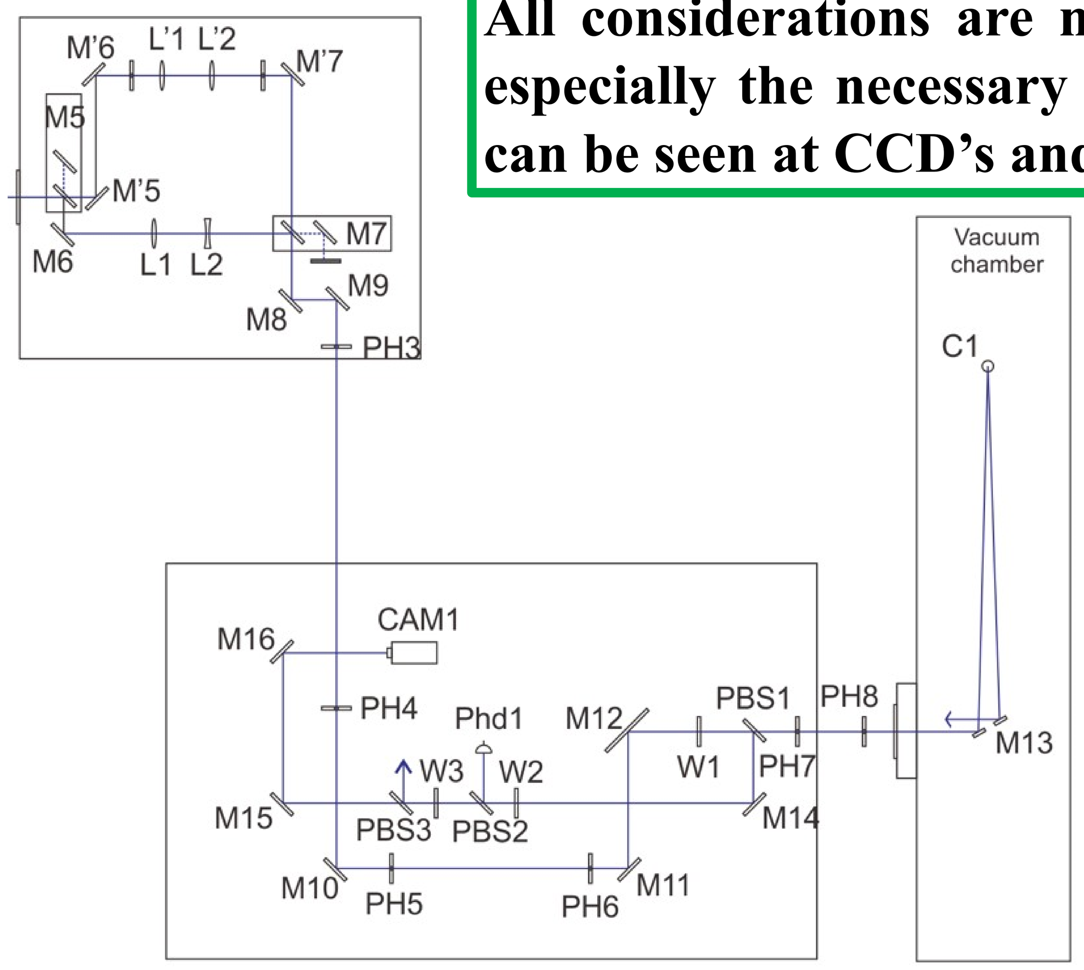

Figure 2. Detailed LTL final focus layout of KEK LUCX: M is the mirror, L is the lens, PH is the pinhole, PBS is the polarized beam splitter, W the is the wave plate, CAM is the CCD camera and Phd the is photodiode

$$Dsp = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix}, \qquad (1)$$

Dsp is the drift space transfer matrix, ***L*** is the drift space

$$Fl = \begin{pmatrix} 1 & 0 \\ -1/f & 1 \end{pmatrix}, \qquad (2)$$

Fl is the focusing length transfer matrix, ***f*** is the focus length

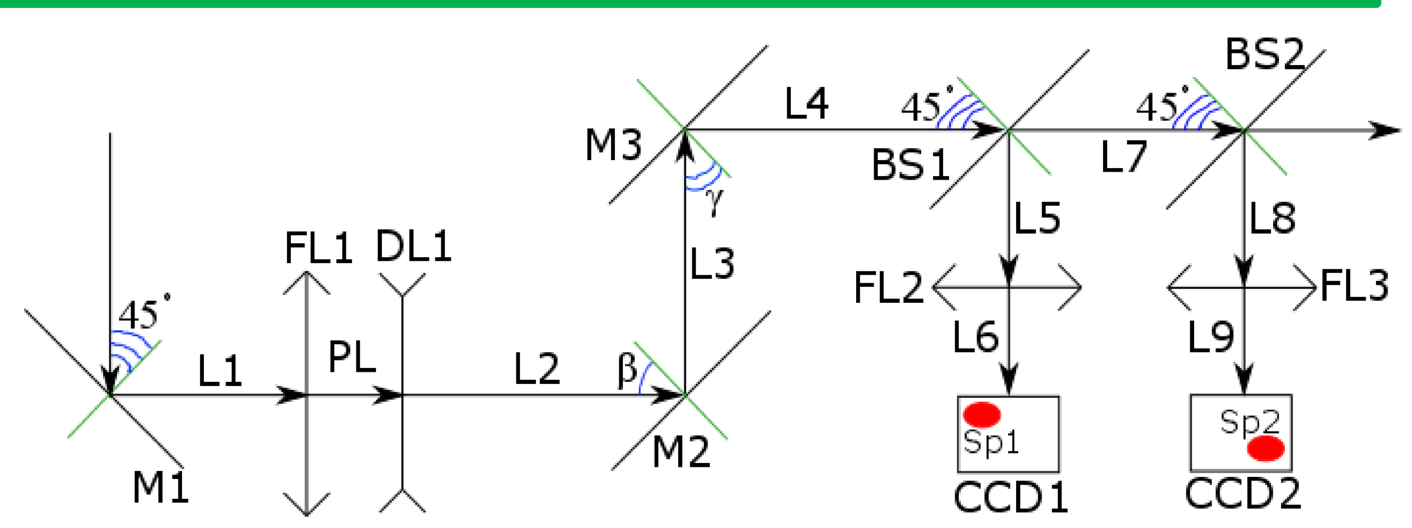

Figure 3. Simplified LTL final focus layout of KEK LUCX: M is the mirror, L is the drift space, FL and DL is the focusing and defocusing lenses, BS is the beam splitter, CCD is the camera

$$\begin{pmatrix} X_{ccd1} \\ \theta_{ccd1} \end{pmatrix} = Dsp1 \cdot Fl2 \cdot Dsp2 \cdot \begin{pmatrix} X_{M2} \\ \theta_{M2} \end{pmatrix} \qquad (3)$$

$$\begin{pmatrix} X_{ccd2} \\ \theta_{ccd2} \end{pmatrix} = Dsp1' \cdot Fl3 \cdot Dsp2' \cdot \begin{pmatrix} X_{M2} \\ \theta_{M2} \end{pmatrix} \qquad (4)$$

In reality we are able to measure only **position shift** of X_{ccd1} and X_{ccd2} , but to correct it we should change the mirror angle θ_{M2}. After solving Eq. 3 and Eq.4, it is possible to calculate X_{M2} and θ_{M2} and recalculate $\Delta\theta_{M2}$ via ΔX_{ccd1} and ΔX_{ccd2} to realign LTL.

$$\Delta\theta_{M2} = \frac{X1 \cdot \Delta X_{ccd1} - X3 \cdot \Delta X_{ccd2}}{X1 \cdot X4 - X3 \cdot X2} \qquad (5)$$

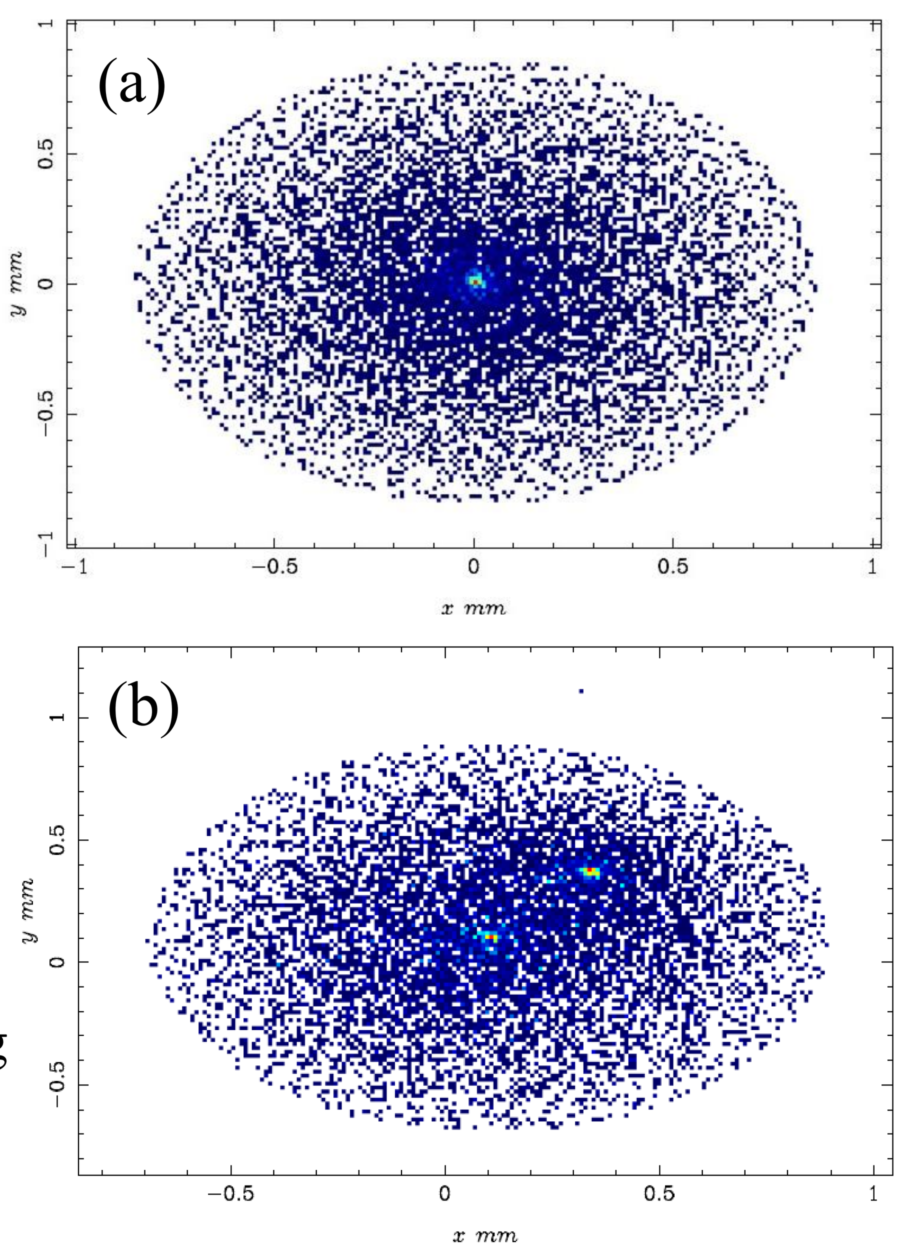

Figure 4. Beam transverse profile at MS1G monitor: (a) is on-axis dynamics, (b) is off-axis dynamics

$$X1 = (1 - L6/f) \qquad (6)$$

$$X2 = \left(\left(1 - \frac{L6}{f}\right) \cdot A1 + L6\right) \qquad (7)$$

$$X3 = (1 - L9/f) \qquad (8)$$

$$X4 = \left(\left(1 - \frac{L9}{f}\right) \cdot A2 + L9\right) \qquad (9)$$

$$A1 = L3 + L4 + L5 + L6 \qquad (10)$$

$$A2 = L3 + L4 + L7 + L8 + L9 \qquad (11)$$

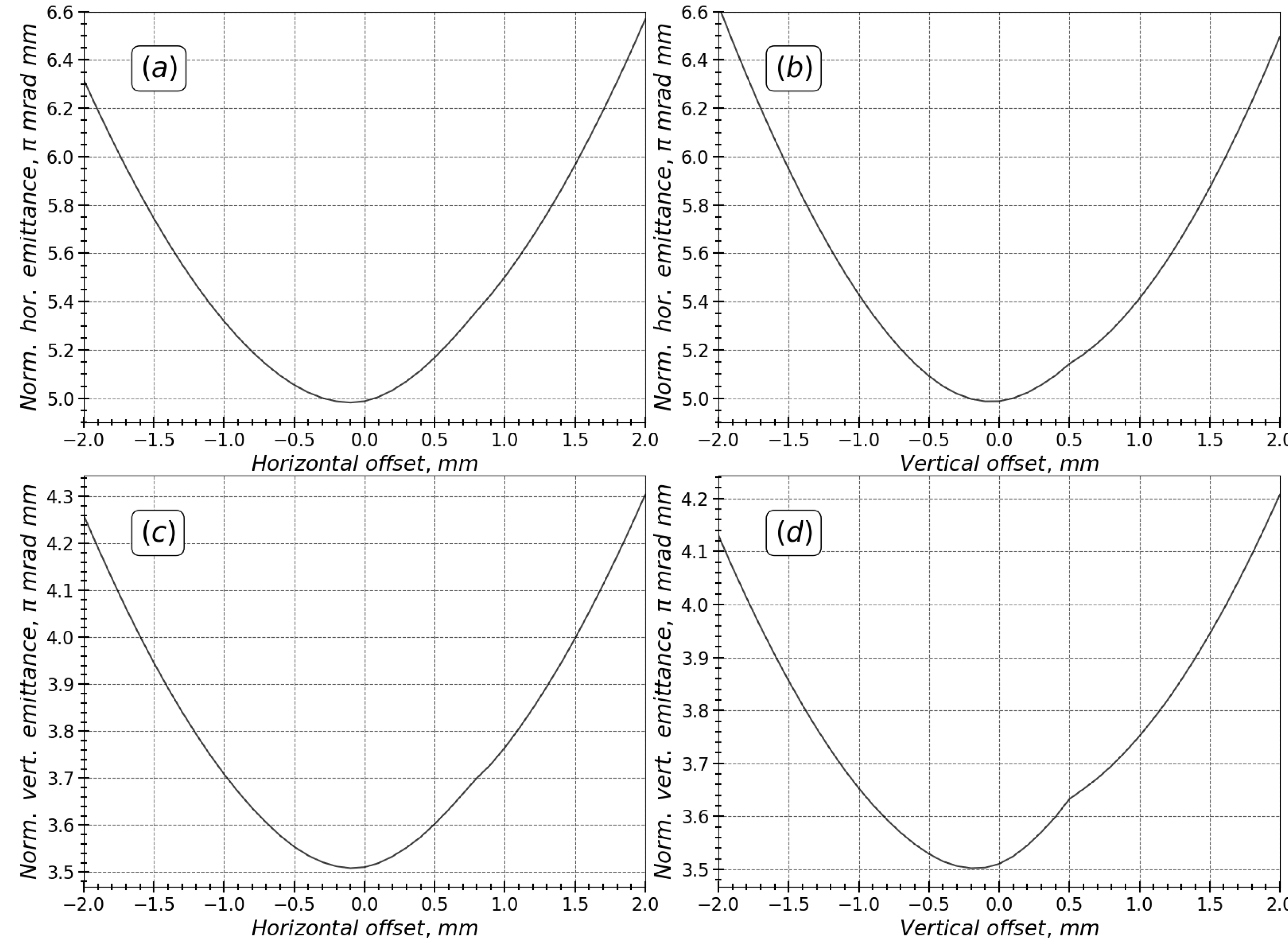

Figure 5. Normalized emittance at CP1G monitor versus laser spot position on photocathode: (a) is the normalized horizontal emittance vs horizontal offset, (b) is the normalized horizontal emittance vs vertical offset, (c) is the normalized vertical emittance vs horizontal offset, (d) is the normalized vertical emittance vs vertical offset

LTL alignment procedure

1)Measurement of the laser beam transverse sizes (X_{ccd1} ,X_{ccd2}) and centroid offset (ΔX_{ccd1} , ΔX_{ccd2}) at two locations (CCD1 and CCD2) along a beam path.

2)Using Eq.5 the angular correction for mirror 2 can be calculated.

3) The input beam size on the photocathode can be calculated and reconfirmed with measured one on the virtual cathode.

References

*A. Aryshev et al., Appl. Phys. Lett. 111, 033508 (2017).

**https://www.jai.com/products/cm-040-ge