MULTIPLE SYNCHROTRON LIGHT MONITORS FOR TRANSVERSE MATCHING AND MONITORING AT CEBAF

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ABSTRACT

Beam setup at the Continuous Electron Beam Accelerator Facility (CEBAF) involves threading beam through the machine and monitoring global transfer functions to identify and address cumulative lattice errors. Transverse beam emittance may grow by as much as two orders of magnitude, mediated by synchrotron radiation. Re-matching the enlarged beam phase space into successive re-circulation arcs minimizes this emittance growth but requires knowledge of the actual beam distribution. This is now accomplished through quadrupole scans using wire profile monitors, the most time-consuming activity in our setup process. We propose to use Synchrotron Light Monitors (SLMs) to image the beam at homologous points in the four super-period re-circulation arc lattices. Benefits include real-time monitoring of beam parameters and reduced elapsed time for initial setup. These SLMs will be installed in Arc 7 of the CEBAF machine, where Synchrotron Radiation contributes moderately to emittance growth. One of four required SLMs will be installed and commissioned this year, with the rest being installed next year.

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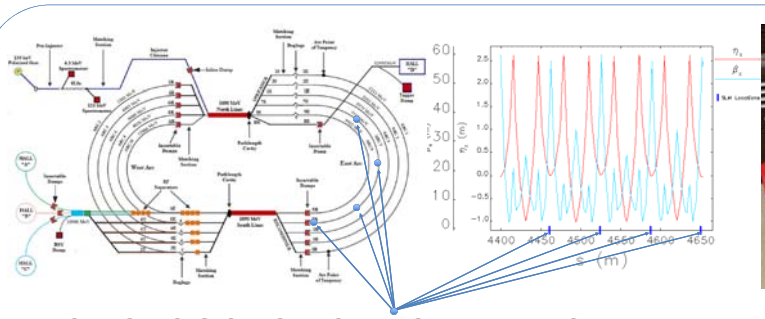
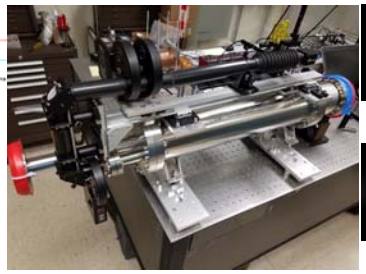
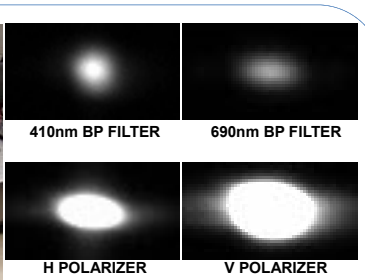


HOMOLOGOUS POINTS IN THE SUPER-PERIOD RE-CIRCULATION ARC LATTICE



1ST ARC 7 SLM



SLM IMAGE

SOLVING FOR THE TWISS PARAMETERS

$$\begin{pmatrix} (\sigma_x^{(1)})^2 \\ (\sigma_x^{(2)})^2 \\ (\sigma_x^{(3)})^2 \\ \cdots \\ (\sigma_x^{(n)})^2 \end{pmatrix} = \begin{pmatrix} (R_{11}^{(1)})^2 & 2R_{11}^{(1)}R_{12}^{(1)} & (R_{11}^{(1)})^2 \\ (R_{11}^{(2)})^2 & 2R_{11}^{(2)}R_{12}^{(2)} & (R_{11}^{(2)})^2 \\ (R_{11}^{(3)})^2 & 2R_{11}^{(3)}R_{12}^{(3)} & (R_{11}^{(3)})^2 \\ \cdots & & \\ (R_{11}^{(n)})^2 & 2R_{11}^{(n)}R_{12}^{(n)} & (R_{11}^{(n)})^2 \end{pmatrix} \begin{pmatrix} \beta(s_0)\epsilon \\ -\alpha(s_0)\epsilon \\ \gamma(s_0)\epsilon \end{pmatrix}$$

"MULTIPLE WIRE MEASUREMENTS" MATRIX SOLVE FOR TWISS PARAMETERS ϵ, $\beta(s_0)$ AND $\alpha(s_0)$

$(\sigma_x^{(n)})^2$ – MEASURED PROFILES FROM THE FOUR SLMS

$R_{mn}^{(n)}$ – TRANSFER MATRIX ELEMENTS FORM LATTICE DESIGN

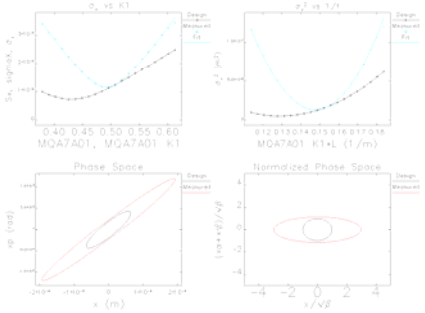
TWISS PARAMETERS:

ϵ – RELATED TO THE BEAM SIZE AND PHASE ELLIPSE AREA (A = π * ϵ)

β – RELATED TO THE SIZE AND SHAPE OF THE BEAM

α – BEAM TILT OR THE EXTENT OF BEAM CONVERGENCE OR DIVENGENCE

INITIAL RESULTS



SLM QUADRUPOLE SCAN DATA PLOTTED BY THE ANALYZER TOOL. DESIGN VALUES ARE ALSO PLOTTED FOR COMPARISON.

ERROR SOURCES

1. CHROMATIC ERROR, DUE TO THE LIGHT NOT BEING MONOCHROMATIC. THIS ERROR IS REDUCED BY USING BAND-PASS FILTERS AND ACHROMATIC LENSES.
2. DEPTH OF FIELD $\Delta F \approx (L/2)\,\theta$, WHERE L IS THE LENGTH OF THE SOURCE AND θ IS THE HALF-ACCEPTANCE ANGLE.
3. DIFFRACTION ERROR FROM A VERTICAL SLIT $\Delta_{DIFF} = 0.5(\lambda/\theta)$, WHERE λ IS THE WAVELENGTH OF LIGHT THAT IS IMAGED.
4. CURVATURE ERROR $\Delta_{CURV} \approx R\,\theta^2/2$, WHERE R IS THE RADIUS OF BEND. THIS CORRECTION IS ONLY NEEDED IN THE PLANE OF THE BEND, WHICH IN OUR CASE IS IN THE HORIZONTAL PLANE.
5. OTHER ERRORS INCLUDE NON-LINEAR CAMERA RESPONSE (GAMMA-FACTOR) AND MISCELLANEOUS CALIBRATION ERRORS.

CONCLUSIONS

A METHOD OF MEASURING, MATCHING, AND MONITORING FOUR HOMOLOGOUS POINTS IN THE OPTICAL LATTICE OF ONE OF THE TEN CEBAF ARCS HAS BEEN PRESENTED. THE FOUR POINT METHOD SHOULD PROVIDE A QUICK, NON-DESTRUCTIVE METHOD OF MEASURING THE BEAM PROFILES. RESULTS FROM THE FIRST OF THE FOUR HAVE ENABLED TESTING OF THE OPTICAL DESIGN OF THE SLM ASSEMBLY AND THE CONTINUATION OF SOFTWARE DEVELOPMENT. THERE IS MUCH WORK LEFT TO DO. THE NEXT STEPS INCLUDE SOME SIMULATION IN ELEGANT, AS WELL AS FURTHER ANALYZING THE ACTUAL APPLICATION OF THE METHODS FOR SOLVING FOR THE TWISS PARAMETERS.