Transverse Beam Profiling and Vertical Emittance Control with a Double-Slit Stellar Interferometer

J.Corbett[1], X.Huang[1], C.Li[2], T.Mistuhashi[3], J.Wu[1], Y.Xu[4], and W.J.Zhang[2,5]

[1]SLAC National Accelerator Laboratory, Menlo Park, USA

[2]East China University of Science and Technology, Shanghai, China

[3]KEK, Tsukuba, Japan

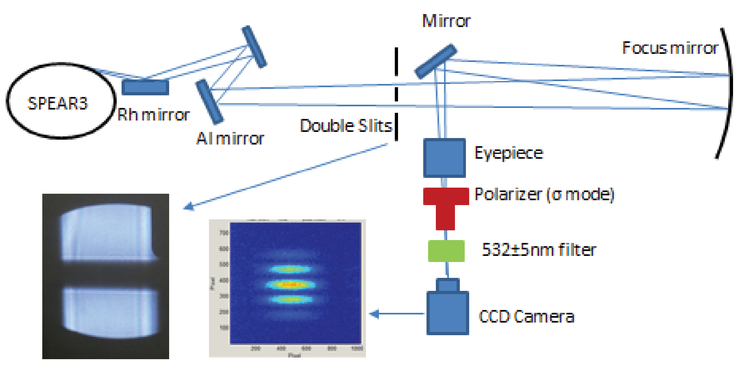
[4]Donghua University, Shanghai, China

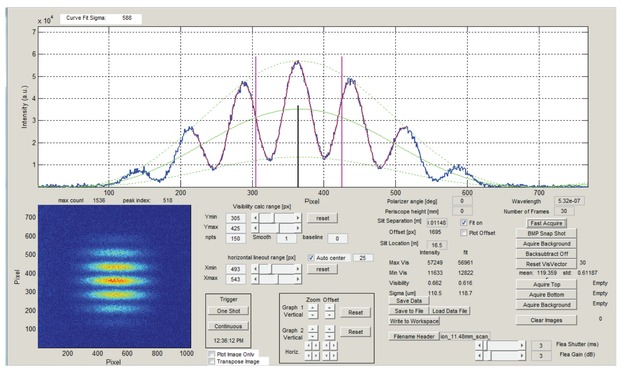
[5]University of Saskatchewan, Saskatoon, Canada

Abstract

- *Double -slit stellar interferometer measures the transverse size of relativistic charged particle beams*
- *Describe the double-slit interferometer at SPEAR3 and develop a theoretical framework for the interferometer*
- *Rotating the double-slit, the transverse beam profile can be reconstructed including beam tilt at the source.*
- *Demonstrate the use of the SPEAR3 visible-light interferometer for emittance control using the Robust Conjugate Direction Search (RCDS) optimal search algorithm.*

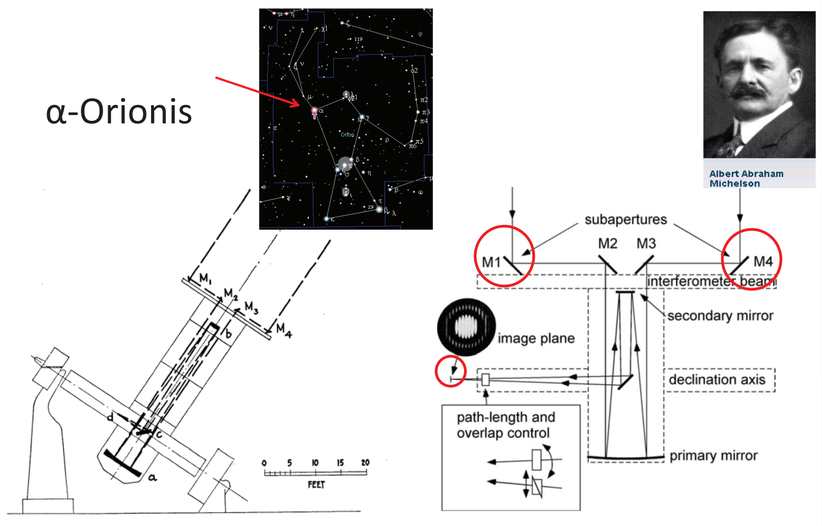
SPEAR3 Interferometer System





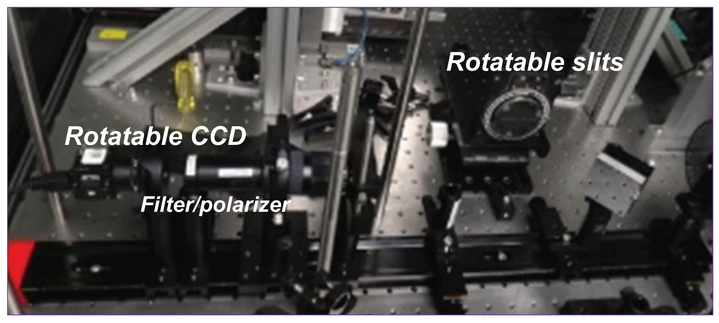
- *20um x 120um source point*
- *60mm x 150mm unfocused beam*
- *150mm reflective mirror: f=+120mm*
- *Commercial telescope objective*
- *Double slit and CCD camera on rotation stages*
- *Matlab analysis interface + MML to EPICS*

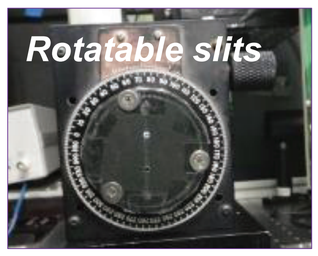
Michelson Stellar Interferometer (1920)



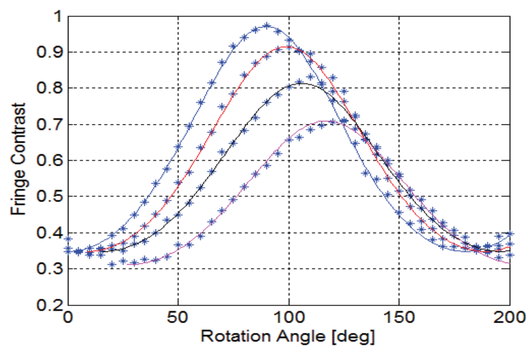
- *For Michelson's interferometer, the ratio between α-Orionis diameter and distance to telescope was ~1×10^{-7}*
- *For SPEAR3, the ratio is ~1-7×10^{-6}*

Rotating interferometer slits

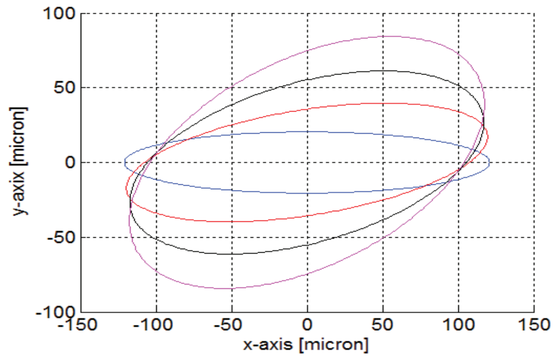




Measurement Results



Contrast measurement and fit with double-slit rotation. Four different coupling conditions



RMS electron beam cross-section for each coupling condition

Van Cittert-Zernike relation in a Rotated Coordinate System

$$\gamma(f_x, f_y) = \iint I(x,y) e^{+i2\pi(f_x x + f_y y)} dxdy$$

For a Gaussian beam in the x-y plane

$$I(x,y) = I_o e^{-\left(\frac{x^2}{2\sigma_x^2} + \frac{y^2}{2\sigma_y^2}\right)}$$

$$\gamma(f_x, f_y) = e^{-\left(\frac{f_x^2}{2\sigma_{\gamma,x}^2} + \frac{f_y^2}{2\sigma_{\gamma,y}^2}\right)}$$

$f = \frac{d}{\lambda L} m^{-1}$ = the spatial frequency

d-slit separation

L-source-to-slit distance

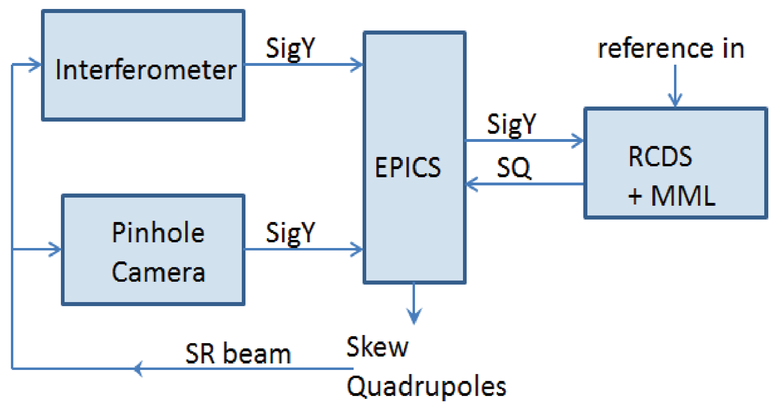
Rotating the double slits by angle θ

$$f_x = \frac{d}{\lambda L} cos\theta \text{ and } f_y = \frac{d}{\lambda L} sin\theta$$

The coherence function becomes

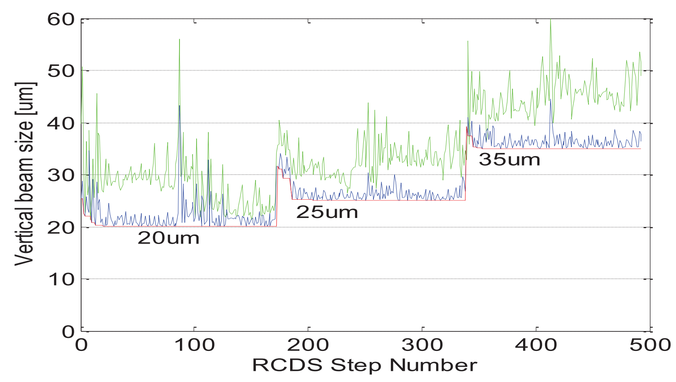
$$\gamma(f_x, f_y, \theta) = e^{-\left(\frac{\left(\frac{d}{\lambda L} cos\theta\right)^2}{2\sigma_{\gamma,x}^2} + \frac{\left(\frac{d}{\lambda L} sin\theta\right)^2}{2\sigma_{\gamma,y}^2}\right)}$$

Robust Conjugate Direction Search for vertical beam size control (RCDS)

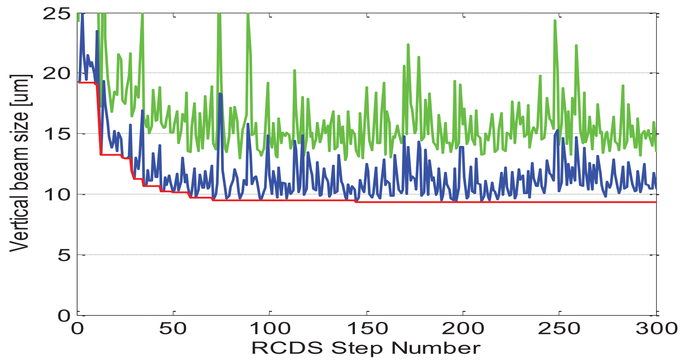


Architecture for RCDS experiment. Vertical interferometer and pinhole camera report σ_y to EPICS. RCDS calculates skew quad settings to control σ_y.

Measurement Results



Vertical beam size reference set to 20um, 25um and 30um at the interferometer (blue). Pinhole camera in green



Reduction to σ_y=9.5 um with RCDS objective function set to zero

Summary

- *SPEAR3 has a diagnostic beam line with unfocused visible light 16m from the source*
- *Rotation of the double-slit mask with respect to the beam axis yields a modulated fringe contrast profile in agreement with theory*
- *The interferometer was applied as a measurement tool to control vertical electron beam size using the Robust Conjugate Directional Search algorithm (RCDS)*

We would like to thank the China Scholarship Council and members of the SPEAR3 operations team for support of this work.