A laboratory experiment to measure the intensity profile of a luminous light source

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The Riddle

- How to measure the luminous intensity distribution of an object that is far away with a small angular spread?

Summary of the journey of discovery

- The Young’s double pin-holes interference
- The definition of visibility = the degree of coherence
- The visibility curve of the Young’s experiment is similar to the diffraction pattern from the an aperture (the extended source)-- illuminated with a monochromatic light producing the same light intensity distribution over the aperture – Von Citterut & Zernike
- The visibility curve of the Young’s experiment does not change with propagation through lens - Zernike

Definition of coherence

- The degree of coherence of two light vibrations shall be equal to the visibility of the interference fringes that may be obtained from them under the best circumstances.

$$\frac{I\ max - I\ min}{I\ max + I\ min}$$

Design of the experiment

- Monochromatic light source– LED
- Two slits separated at variable distance – Alan wrench double slit.
- Recording the interference pattern – CCD camera
- Lens to

Synchrotron Light Interferometer

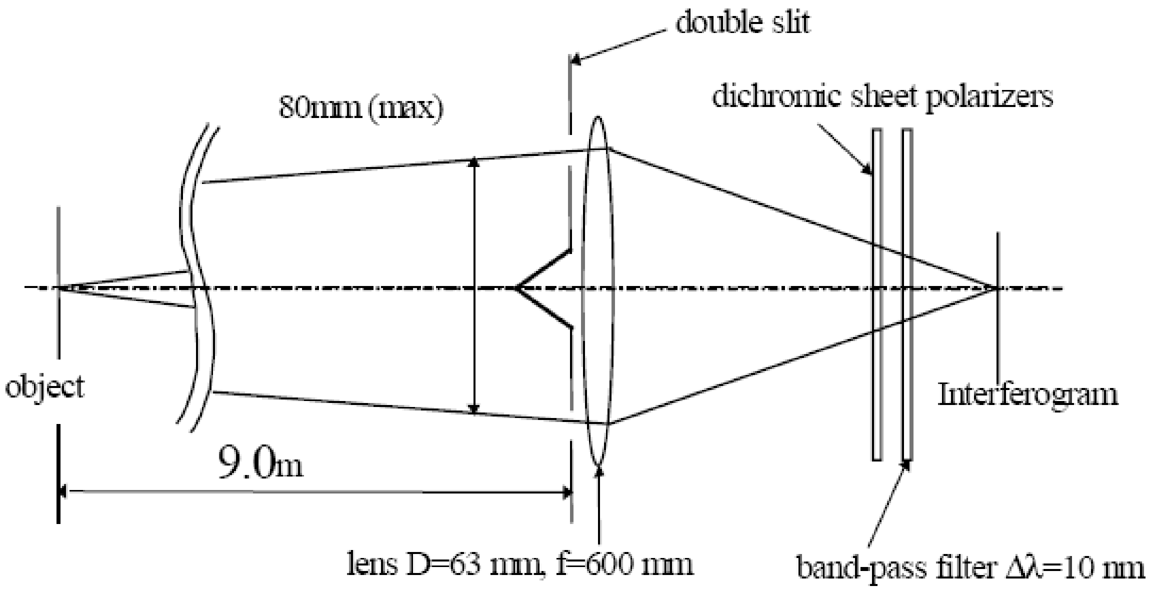
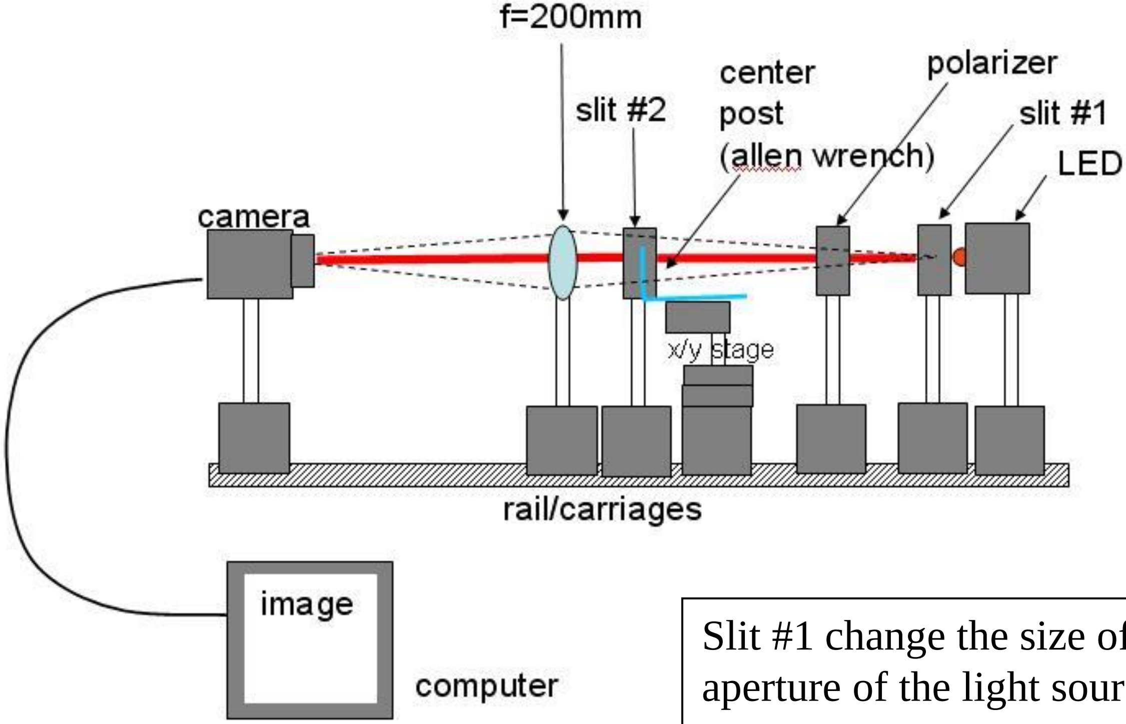


Fig.1 Outline of the SR interferometer.

SR light, X-ray beam Block, Double slit, Polarizer, Filter, CCD camera

Laboratory simulation

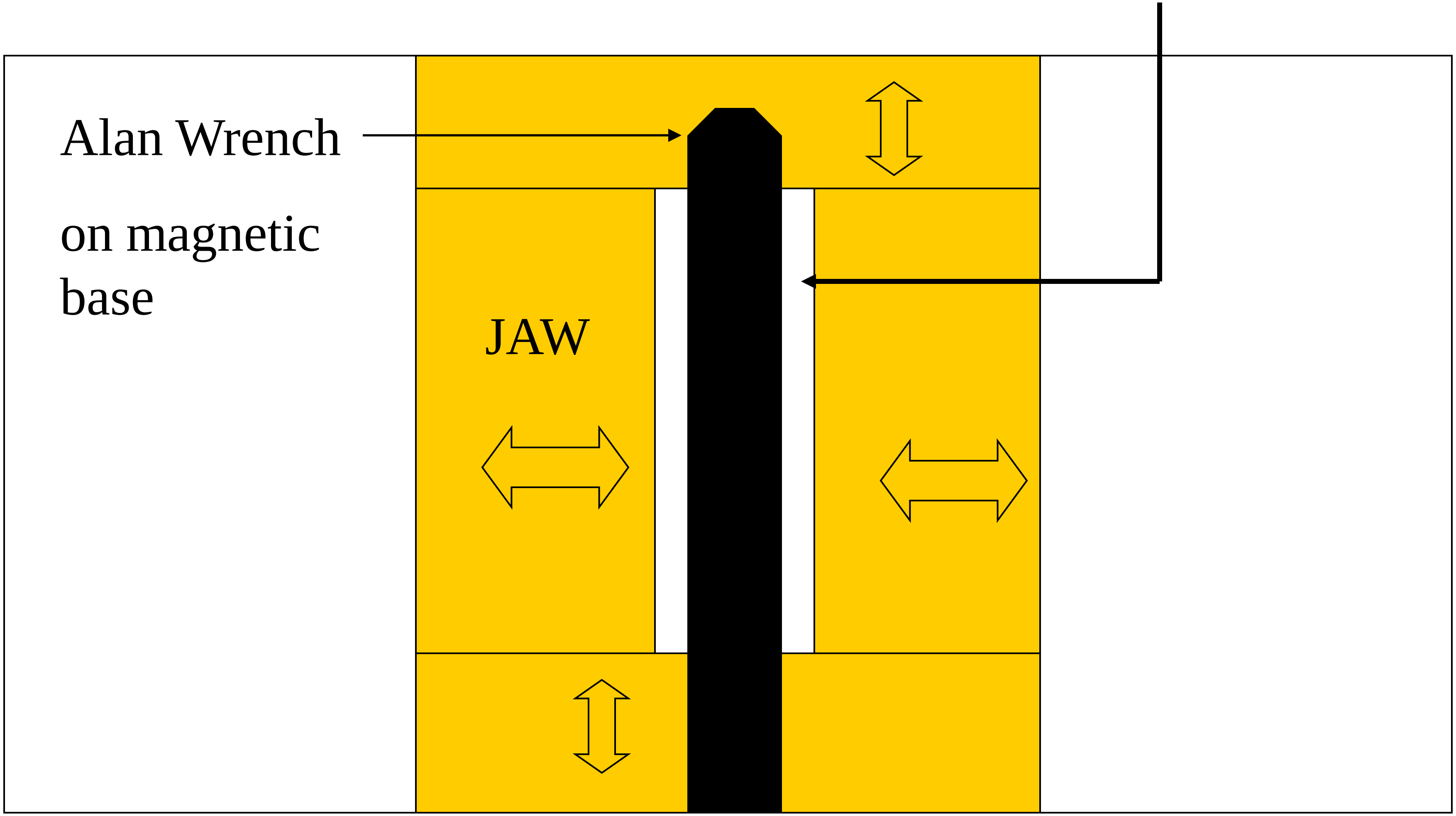
Figure 1: Interferometer setup with CCD camera



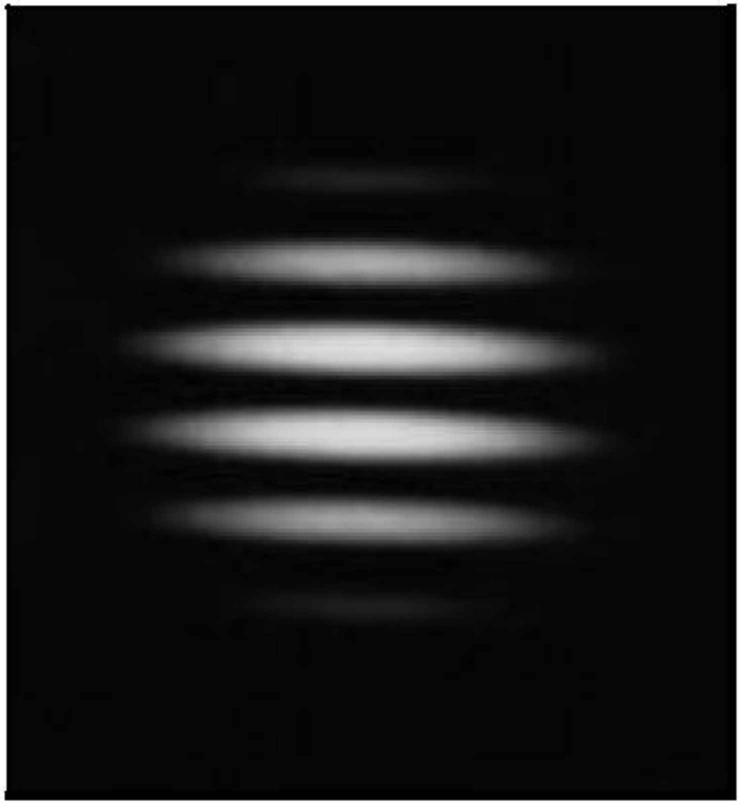
Slit #1 change the size of the aperture of the light source

Slit # 2 two slit with variable center to center distance

Construction of a double slit

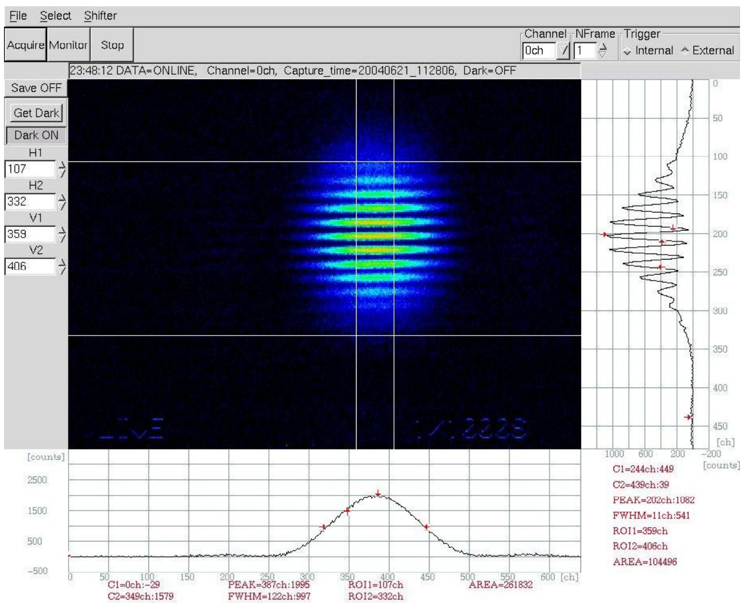


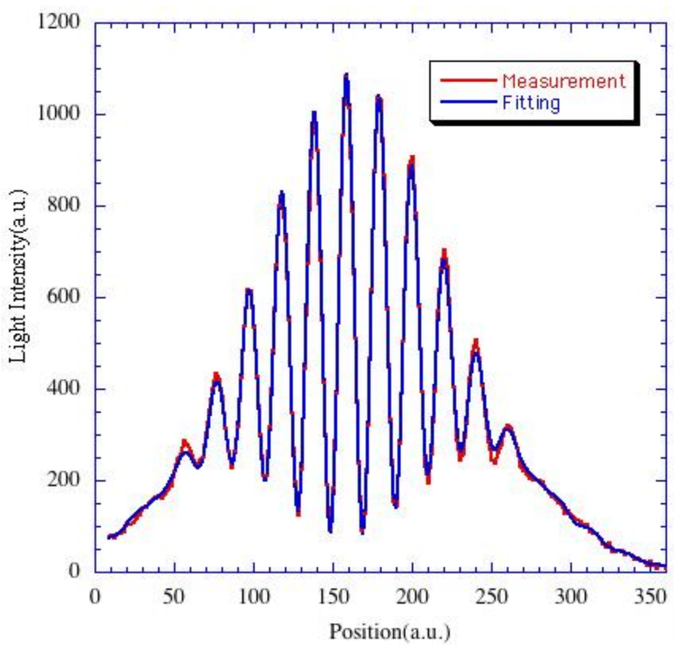
Typical interferogram on the camera



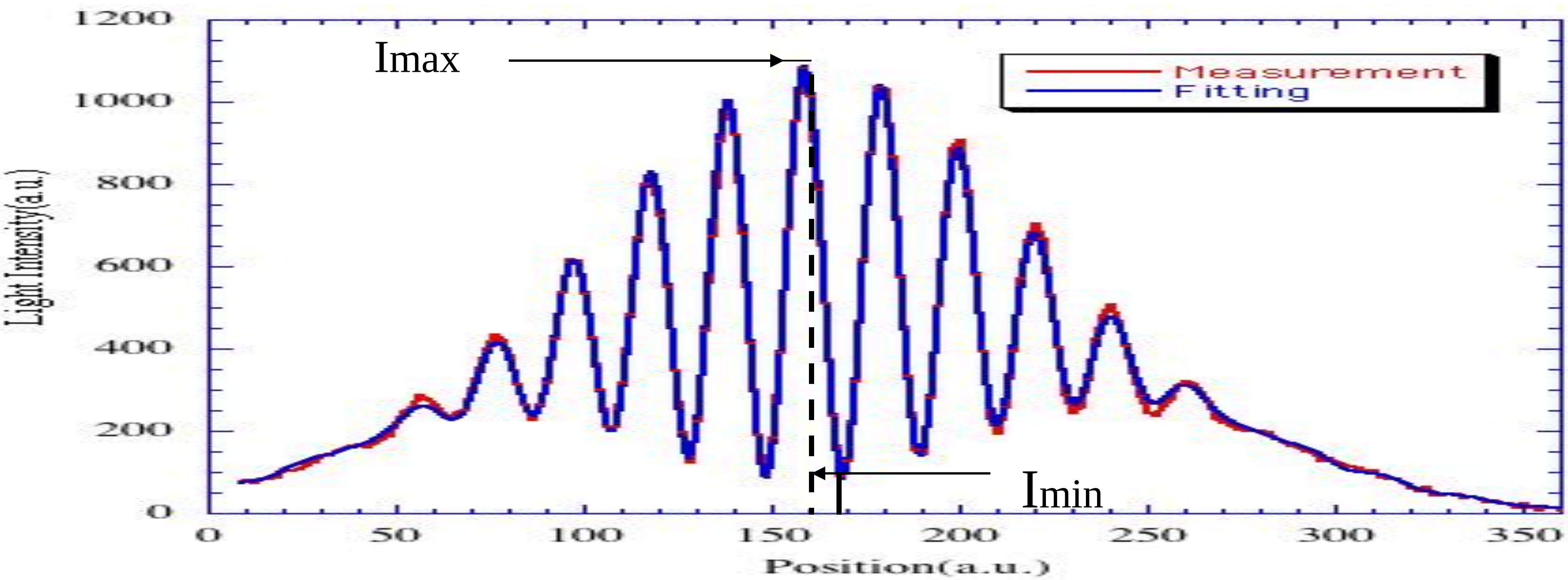
Example of interferogram

D=40mm, λ=400nm

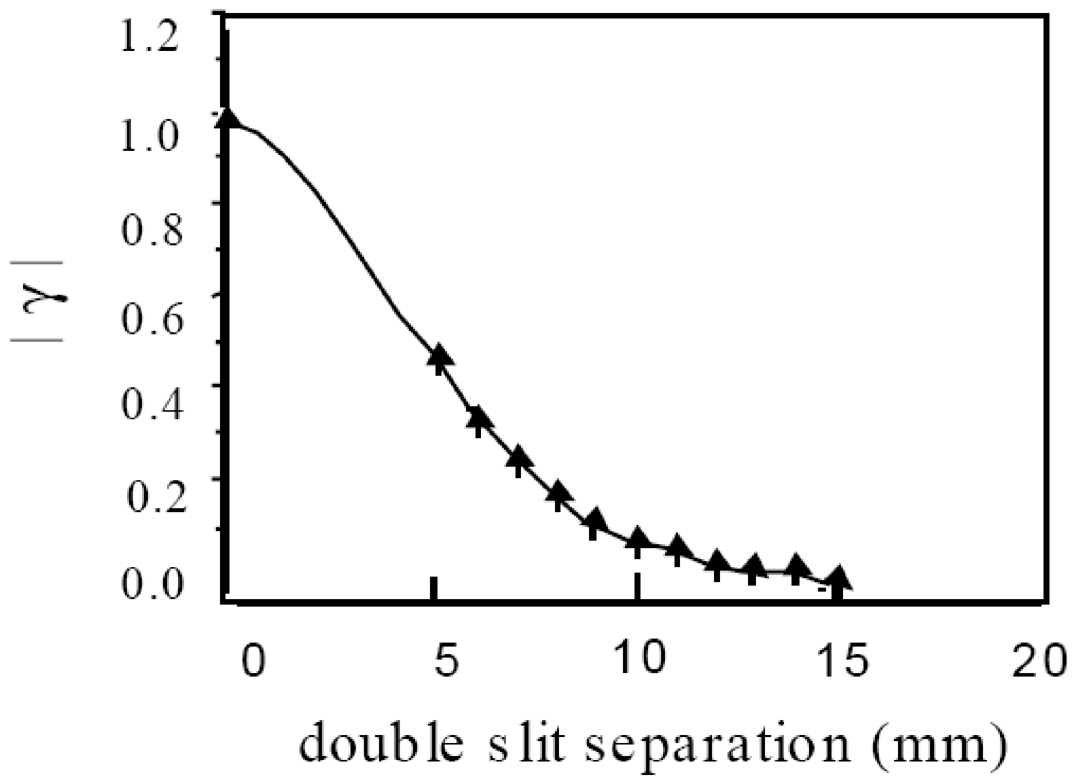




Measurement of visibility



Plotting of visibility vs. slit separation (size of Alan wrench)



Three ways to measure beam size

- From one visibility data point
- Gaussian approximation of beam profile
- Fourier Transform

1-D van Citterut-Zernike's theorem

$$\gamma(\upsilon) = \int f(y) \exp(-2\pi i \upsilon \cdot y) dy , \quad \upsilon = \frac{2\pi \mathrm{D}}{\lambda R} .$$

Where γ is the complex degree of spatial coherence

$f(y)$ is the beam profile as a function of y

R is distance between source beam and the double slit

D is the distance between the slit

Small beam size measurement by means of Gaussian Approximation of beam profile

The RMS beam size is related to the RMS width of the visibility curve.

$$\sigma_{beam} = \frac{\lambda \cdot R}{2 \cdot \pi \cdot \sigma_{\gamma}}$$

Calculate the beam size from one data point of visibility

$$\sigma_{beam} = \frac{\lambda \cdot F}{\pi \cdot D} \cdot \sqrt{\frac{1}{2} \cdot \ln\left(\frac{1}{\gamma}\right)}$$

Where F= source to slit, D=center to center slit separation

Ref: T.Mitsuhashi, “Beam Profile and Size Measurement by SR interferometer” in Beam measurement, Ed. By S. Kurokawa, PP 399-427, World Scientific (1999).

Practical consideration in interferometry

- Wave front error introduced by the optical components deformation due to heat
- Imbalance of intensities of photons passing through a double slit
- Linearity of the CCD camera-calibration is needed.
- We are measuring a time averaged result.