

Part 8

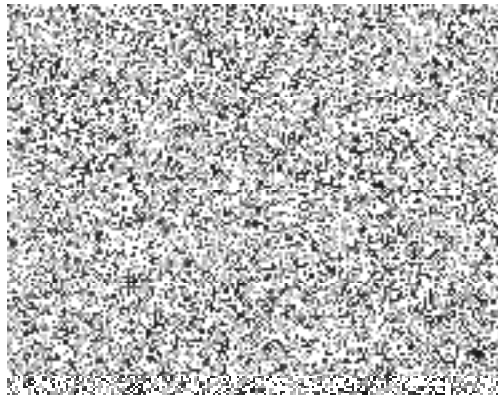
Speckle Interferometry

- **Basic Phenomena**
- **Applications**
 - Out-of-Plane Surface Vibration
 - In-Plane Displacement
 - In-Plane Vibration
 - Stellar Speckle Interferometry
- **Electronic Speckle Pattern Interferometry**

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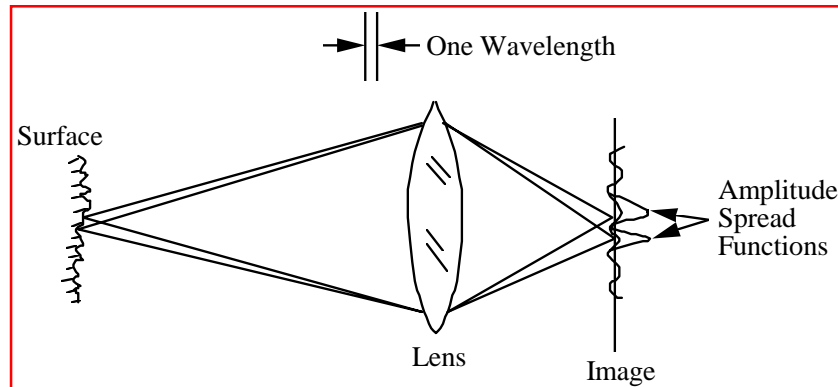
Speckle Pattern Produced by Illuminating a Rough Surface with Laser Radiation



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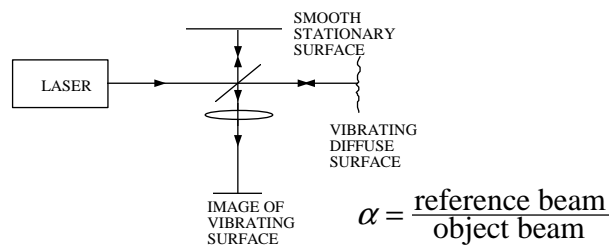
Physical Origin of Speckle for an Imaging System



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Experimental Setup for Measuring Out-of-Plane Surface Vibration



$$\text{Surface Height } z = z_0 + D \sin \omega t$$

$$\text{Speckle Contrast is } C = \frac{[1 + 2\alpha J_0^2(4\pi D / \lambda)]^{1/2}}{1 + \alpha}$$

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Speckle Contrast Reduction Due to Out-of-Plane Vibration

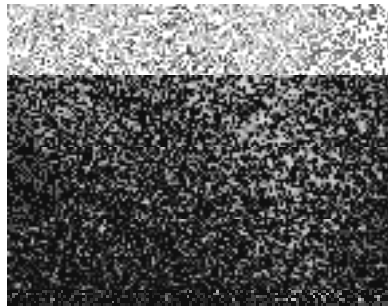


Plate Stationary

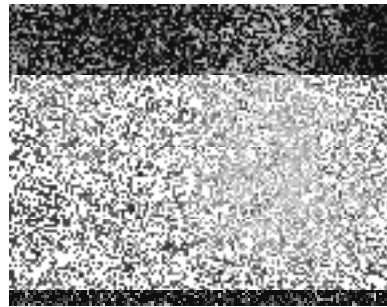
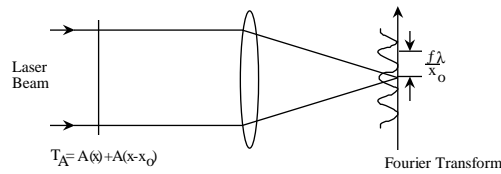
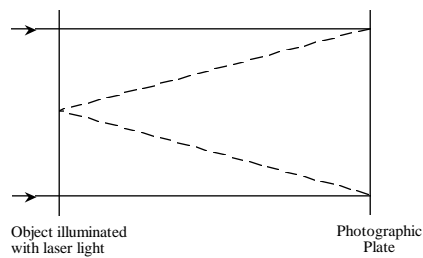


Plate Vibrating

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In-Plane Displacement

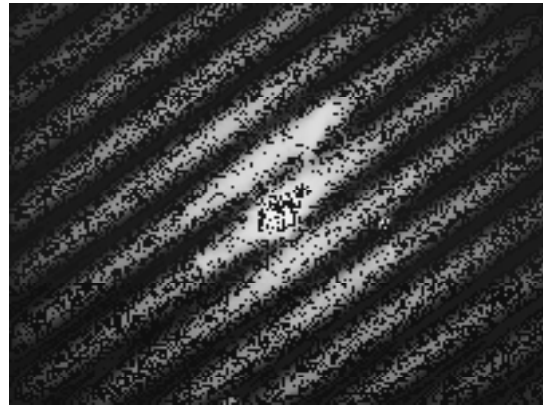


Observing Young's Fringes

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Young's Fringes Resulting from In-Plane Displacement

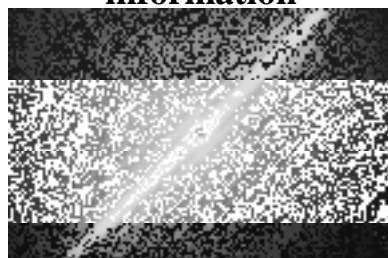


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In-Plane Vibration

- Speckle drawn into lines as surface vibrates
- Diffraction pattern gives vibration information



Linear Motion

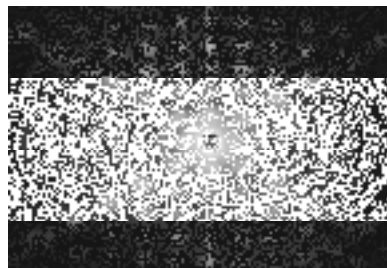


Figure-of-Eight Motion

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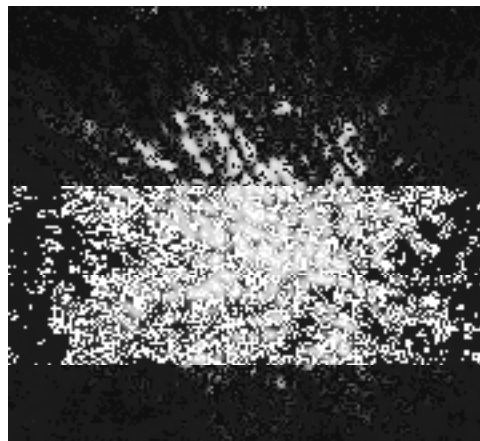
Stellar Speckle Interferometry

- **Atmosphere limits resolution to approximately 1 arc second (10 cm aperture)**
- **Image of star shows speckles if**
 - Exposure time less than period of atmospheric turbulence (1 msec)
 - Spectral bandwidth small (10 nm) so coherence length long
- **Speckle size determined by wavelength and telescope diameter (Diffraction-limited resolution)**
- **Speckles information limited by resolution limit of telescope, not atmospheric turbulence**

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Short Exposure, Narrow Bandwidth, Photograph of Unresolved Star



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Stellar Speckle Interferometry Procedure

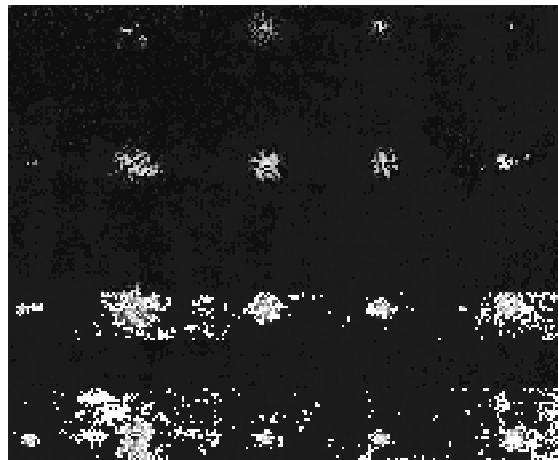
- Take large number, short exposure, photos of object, where each photo is taken for different realization of atmosphere
- Take Fourier transform of each photo (obtain diffraction pattern)
- Add square modulus of diffraction pattern of all photos
- Take Fourier transform of ensemble average of diffraction patterns
- Result is autocorrelation of diffraction-limited image of object

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Stellar Speckle Interferometry Results

object	Photo	Fourier Transform	Sum of 20 Fourier Transforms	Fourier Transform of Sum
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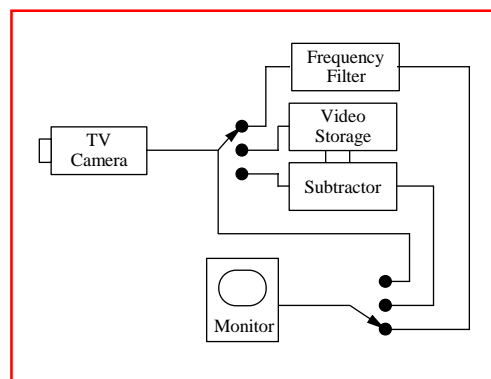
Electronic Speckle Pattern Interferometry (ESPI)

- Use TV system to record speckle instead of film
- Gives real-time measurements
- Minimum speckle size limited by camera resolution
- Can perform computer analysis of speckle data

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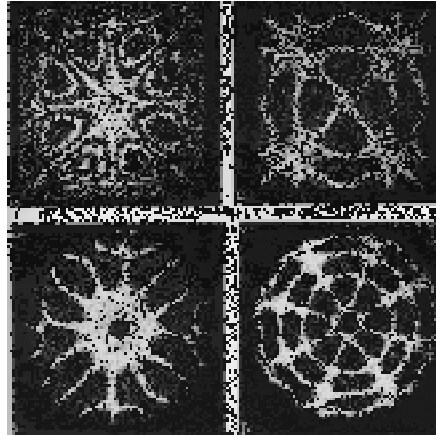
Block Diagram of Electronic Sequence of ESPI System



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Examples of Time-Averaged Vibration Mode Viewing with ESPI



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