Chapter 18
Speech Interferometry

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

Speckle Pattern Produced by Illuminating a Rough Surface with Laser Radiation
**Physical Origin of Speckle for an Imaging System**

![Diagram showing the origin of speckle in an imaging system.](image)

**Experimental Setup for Measuring Out-of-Plane Surface Vibration**

![Diagram showing the experimental setup.](image)

Surface Height: $z = z_o + D \sin \omega t$

Speckle Contrast is: $C = \left[1 + 2\alpha_o^2 \left(\frac{4\pi D}{\lambda}\right)^2\right]^{1/2}$
Speckle Contrast Reduction Due to Out-of-Plane Vibration

Plate Stationary  Plate Vibrating

In-Plane Displacement

Observing Young’s Fringes

Optics 505 - James C. Wyant
Young’s Fringes Resulting from In-Plane Displacement

In-Plane Vibration

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

Linear Motion Figure-of-Eight Motion
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

Short Exposure, Narrow Bandwidth, Photograph of Unresolved Star
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

Stellar Speckle Interferometry Results

<table>
<thead>
<tr>
<th>object</th>
<th>Photo</th>
<th>Fourier Transform</th>
<th>Sum of 20 Fourier Transforms</th>
<th>Fourier Transform of Sum</th>
</tr>
</thead>
</table>

![Image of diffraction pattern]
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

Block Diagram of Electronic Sequence of ESPI System
Examples of Time-Averaged Vibration Mode Viewing with ESPI