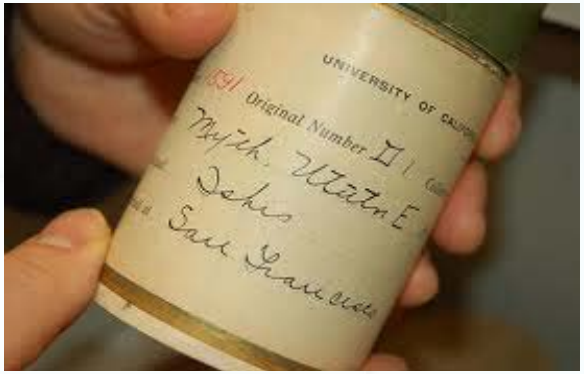
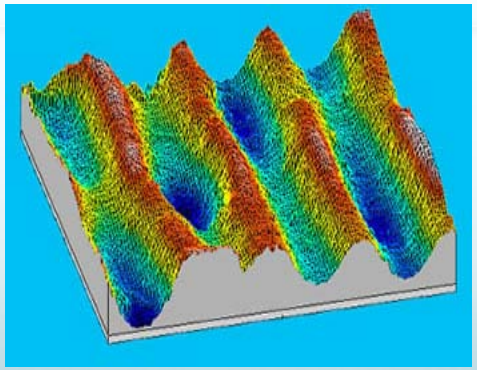
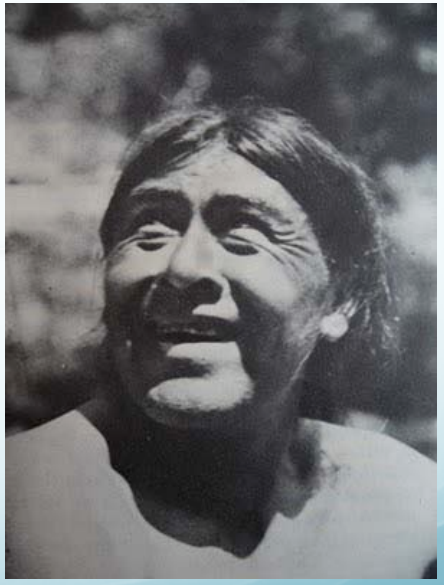


Hearing Ishi's Voice: New Technologies for Audio Restoration

Maryrose Barrios
U.C. Berkeley





The Berkeley Sound Restoration Project

- We are developing methods of restoring mechanical sound recordings **without contact** to the medium – like text scanning
- Address concerns of the preservation, archival, and research communities:
  - Preservation: Restore or stabilize delicate or damaged media
  - Access: Mass digitization of diverse media, automation
  - Assessment
  - Obsolete formats and legacy playback systems
- To date the project has restored some of the earliest experimental and commercial sound recordings.
- We are currently working with the Hearst Museum to restore recordings from their collection.

Collaboration and Support

Lawrence Berkeley National Lab
The Library of Congress
EIF Fribourg, Switzerland

INSTITUTE of Museum and Library SERVICES

The LIBRARY of CONGRESS

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION 1985

Smithsonian Institution

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Cal

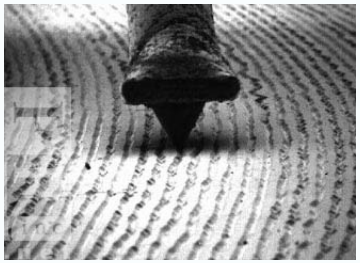
THE ANDREW W. MELLON FOUNDATION

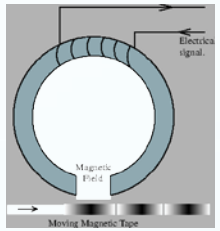
John Simon Guggenheim Memorial Foundation
Fellowships to Assist Research and Artistic Creation

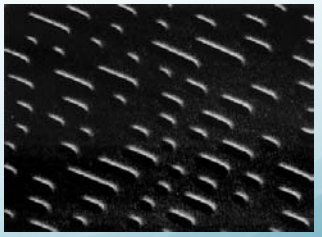
NATIONAL ENDOWMENT FOR THE HUMANITIES

Recording Methods

- Mechanical: a stylus rides in an undulating groove, linked to a diaphragm or pickup (Edison 1877 – 1980's)
- Magnetic: sound is stored in the magnetic orientation of a material (1948 – present)
- Optical: a pattern on film modulates a light beam (1920's – present)
- Digital: sound levels are stored as binary values on magnetic or optical (CD) discs or in a memory chip (1982 – present)



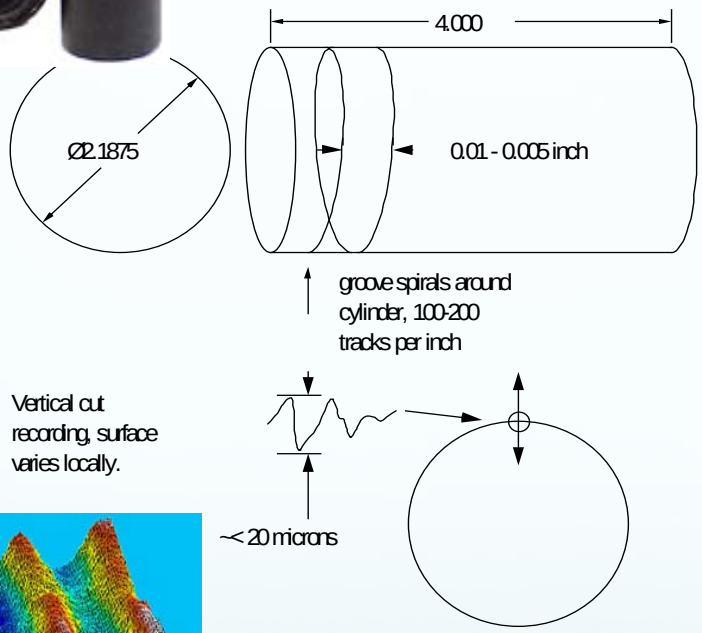


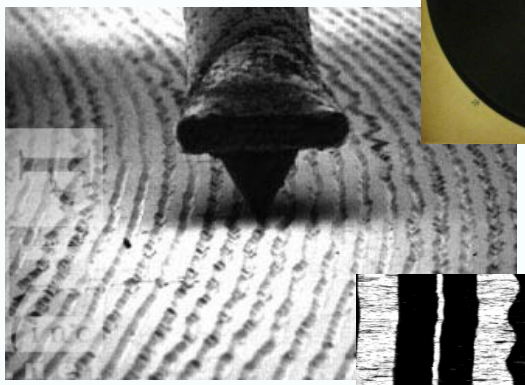


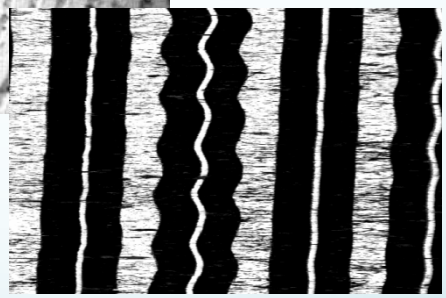
Mechanical Recording Principles

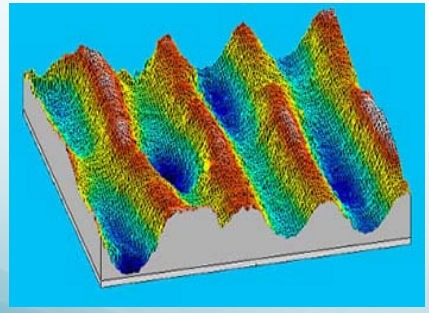
Cylinder: groove varies in depth (Vertical Cut)

Disc: groove moves from side to side (Lateral Cut)





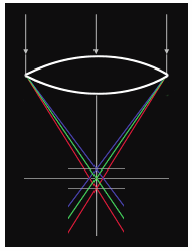


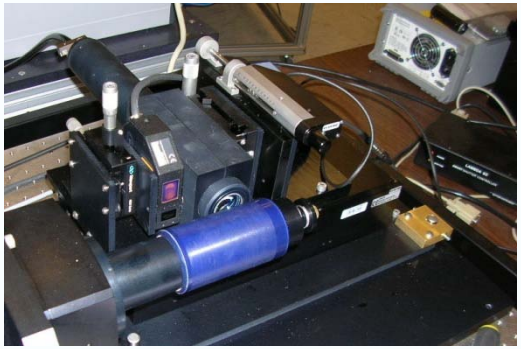


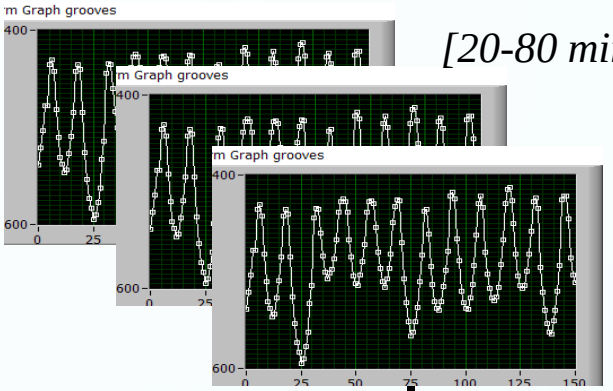
Audio is encoded in micron scale features which are >100 meters long

Basic 3D Scanning Process

Use High-resolution optical probe to create depth profiles of the surface:

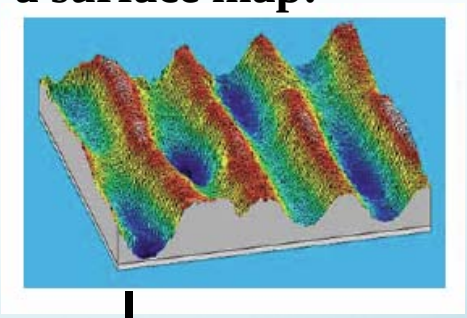




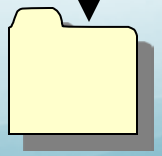


[20-80 mins]

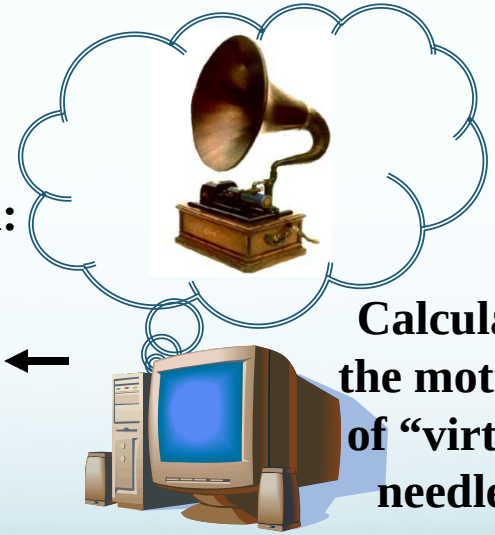
Merge profiles into a surface map:



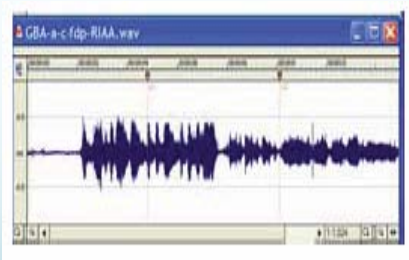
Map is archived



Calculate the motion of "virtual needle"



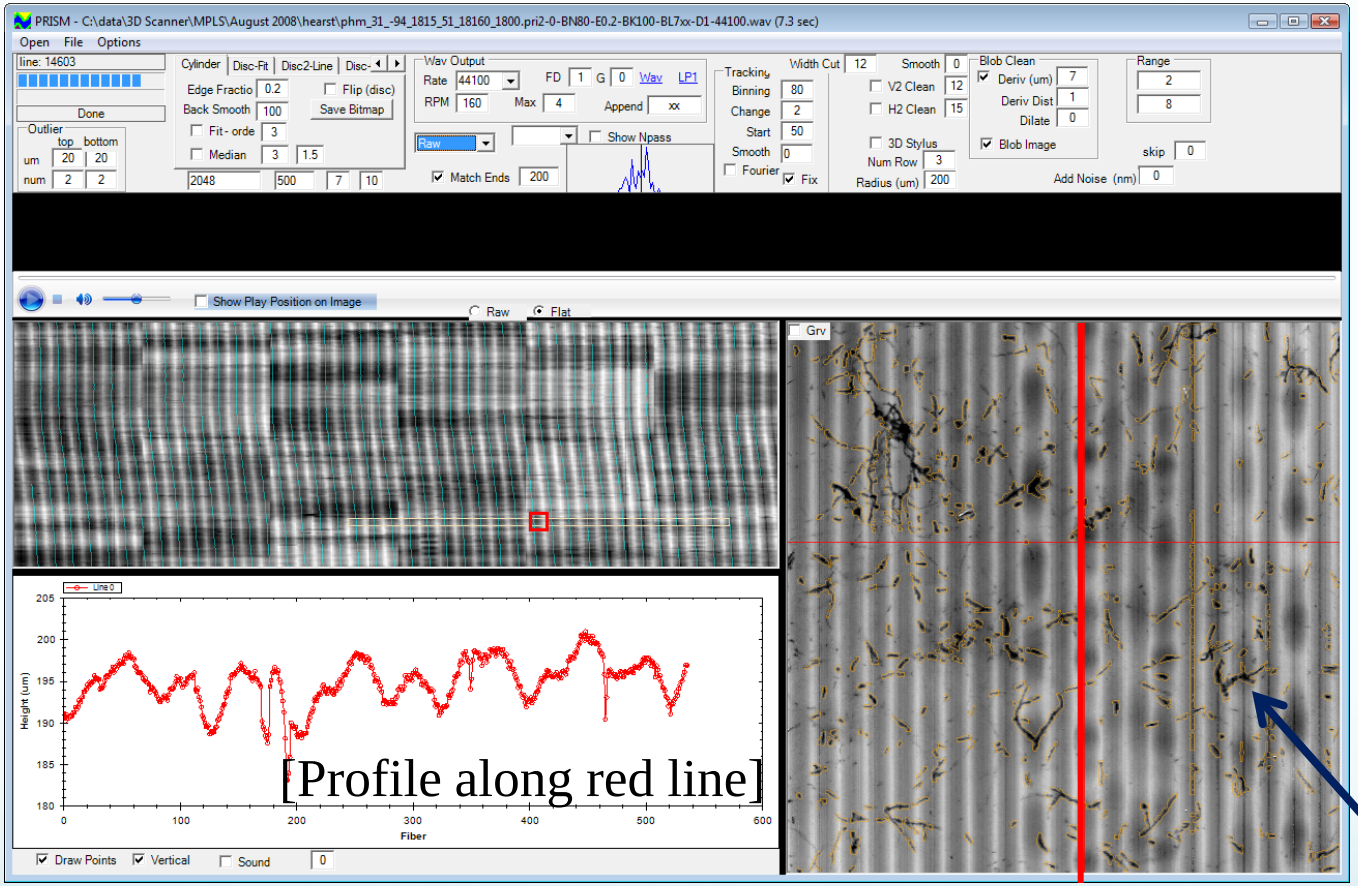
Create audio waveform:



3D Analysis Software

↙Analysis parameters and options ↘

Overview of full ➔ data set



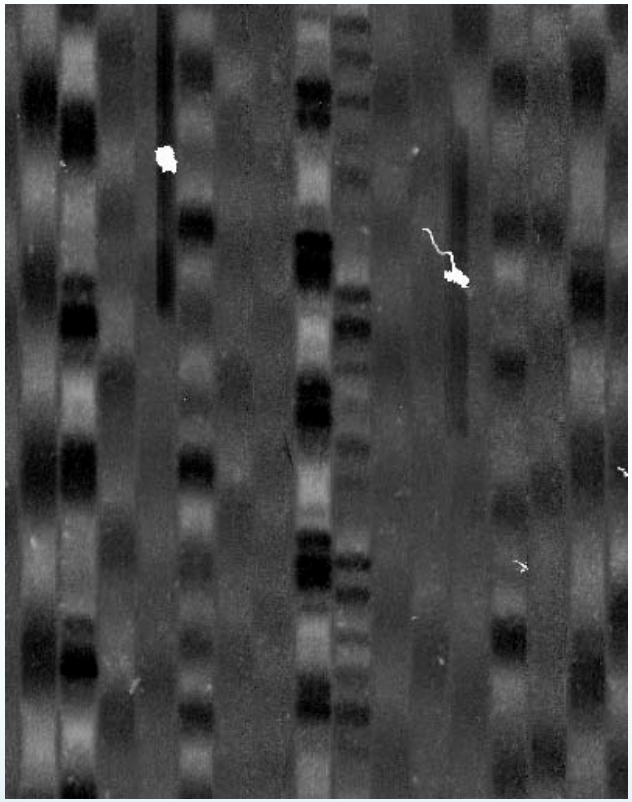
[Zoomed in view]

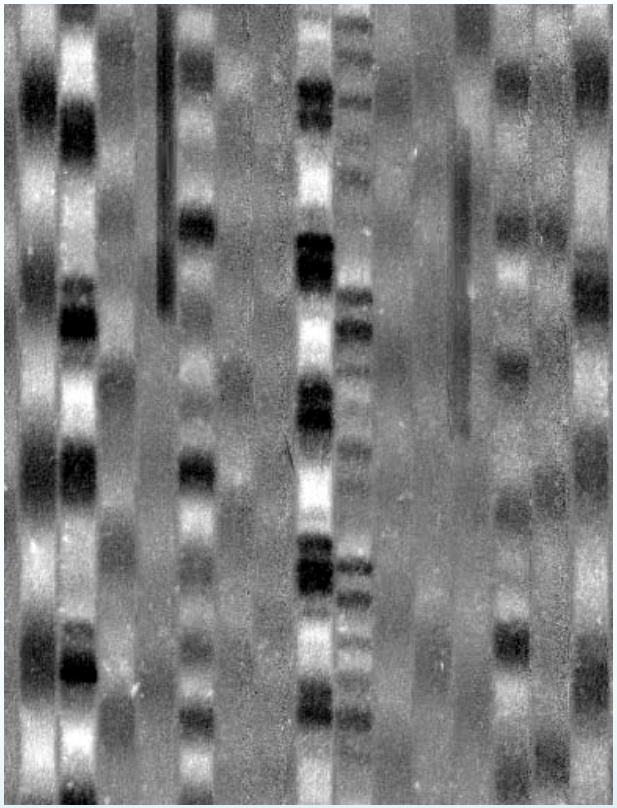
↙*Depth Image*: Black is Deep

Surface damage

The analysis package "PRISM" includes powerful tools and options for access to the data and image processing to remove defects and damage.

Example of Dust Removal





Dust particles appear WHITE because they are above the surface

Hearst Museum Pilot Study

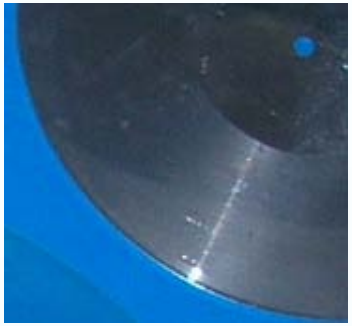
- *2008:* a preliminary study of 11 cylinders was made
- *2008-2011*: considerable improvements to hardware and software
- *May 2011*: begin a larger pilot study
  - Address media with a variety of conditions
  - Assess production issues that occurred
  - Determine best data taking and analysis parameters
  - Maximum throughput was 20 cylinders/week
  - Have completed 60 cylinders to date (23 of Ishi, 10 Yurok, 11 Costanoan, 9 Pomo, 7 Miwok)

Ishi Examples

- Kroeber and colleagues started collecting field recordings in the early 1900's. The Wood Duck collection is from 1911 -- relatively late.
- General condition: the Ishi recordings have particularly small groove amplitudes, and moderate to extensive amounts of mold damage
- *14-1596 Wood Duck Myth*: moderate condition, with localized mold damage
- *14-1593 Wood Duck Myth*: poor condition
- 14-1636 Wood Duck Myth: good condition
- *14-1689 Wood Duck Song:* low mold, very small grooves
- *14-1713 Doctor's Sucking Song*: reasonable condition

Sound Carrier Degradation

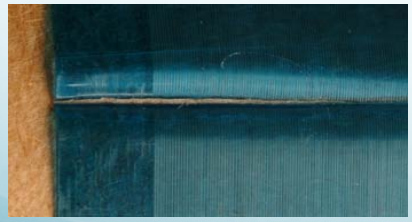
fungus,
mold, &
wax bloom



oxidation

flaking

exudation

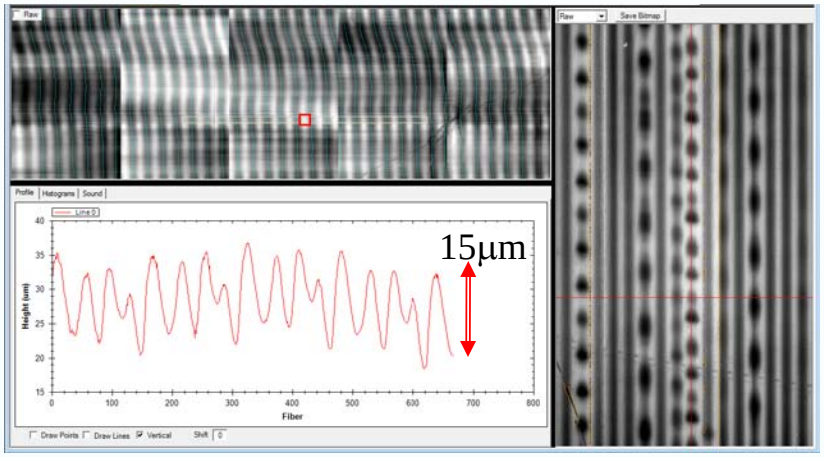


breakage

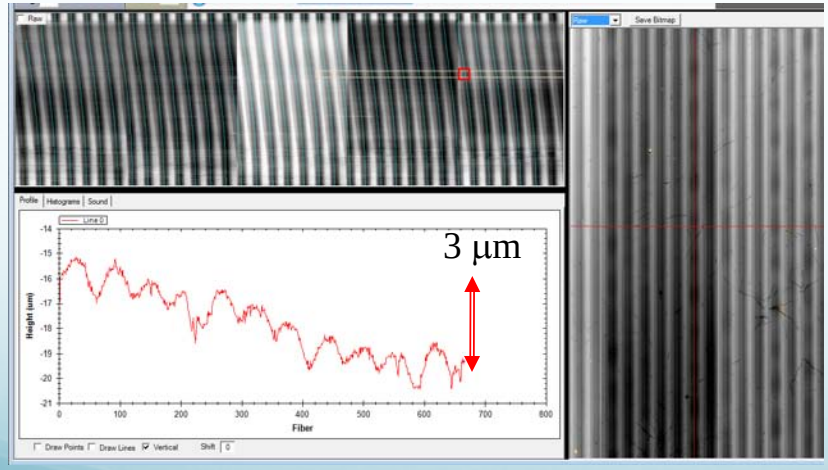
dirt

warpage

Relative Comparison



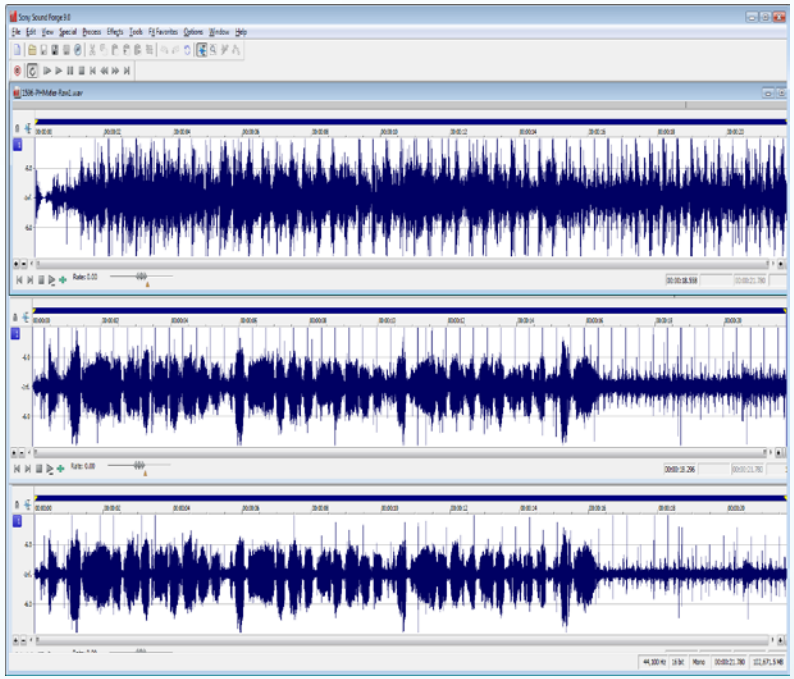
- Clean commercial cylinder of the time.
- Spoken word (French)
- Note groove amplitude ~ 15 microns



- One of the better Ishi cylinders, 14-1636
- Wood Duck story
- Note groove amplitude ~ 1 micron, also noisy

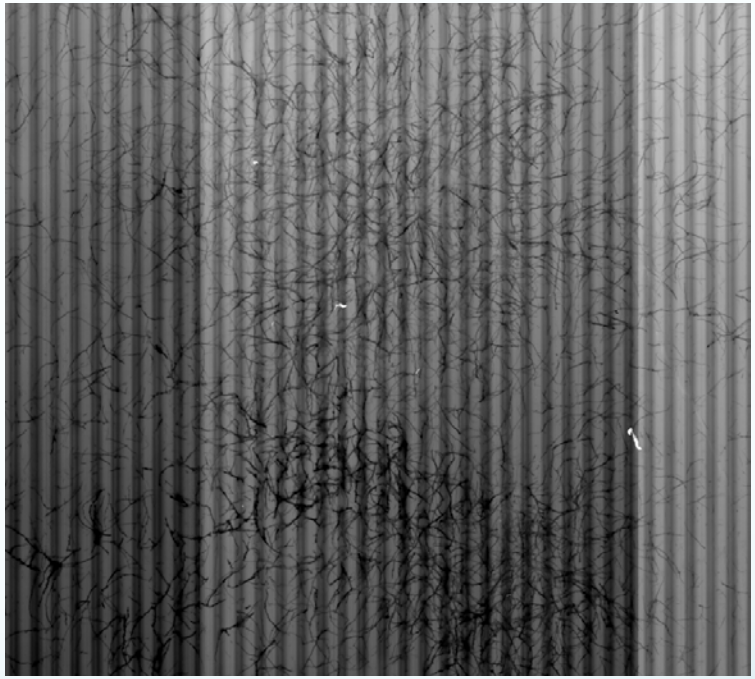
14-1596 Wood Duck Myth (Song)

- Moderate condition with localized mold damage
- Stylus transfer
- 3D transfer “raw”
- 3D transfer “filtered”



14-1593 Wood Duck Myth

- Poor condition with mold damage widely present on the surface
- Stylus transfer
- 3D transfer “raw”
- 3D transfer “filtered”



Depth image: black is deepest, White-to-Black = 400 microns

14-1636 Wood Duck Myth

- Good condition (stylus version not on hand)
- 3D transfer “raw”
- 3D transfer “filtered”

14-1689 Wood Duck Song

- Poor condition
- Stylus transfer
- 3D transfer “raw”
- 3D transfer “filtered”

14-1713: Doctor’s Sucking Song

- Moderate condition
- Stylus transfer
- 3D transfer “raw”
- 3D transfer “filtered”

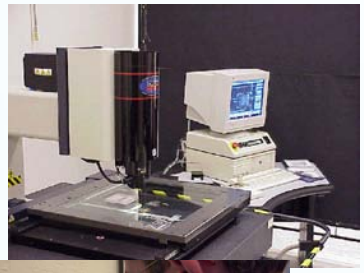
Conclusions

- The optical sound recovery process results in improved sound from these challenging field recorded cylinders
- We have organized a small production pilot project and managed to digitally preserve ~20 cylinders per week, running a single 8 hour shift
  - A 3000 cylinder project would require ~3 years for a single shift/day.
  - We have studied and found optimized measurement and analysis parameters for these materials
  - We have gained experience in the necessary workflow and methodology to carry out larger production projects.
- Project web site: http://irene.lbl.gov

Backup

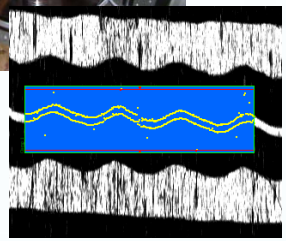
Optical Scanning: Technology Roadmap

Basic **2**D concept demonstration
40 min / 1 sec

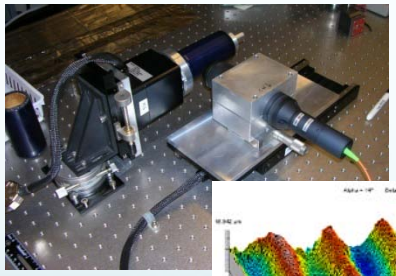


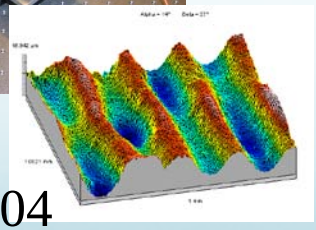
2002

2D disc R&D
4 sec / 1 sec



3D cylinder R&D
20 hr / 1 min





2003-2004

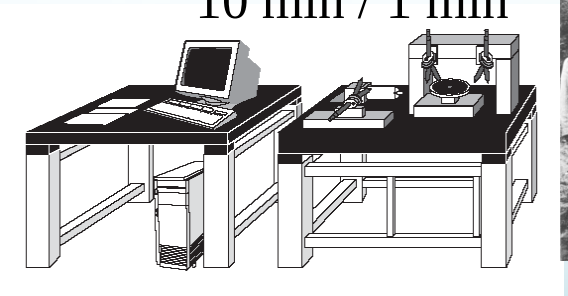
IRENE
System eval

2006-2007

Production mode discs

2009-11

3D System
10 min / 1 min

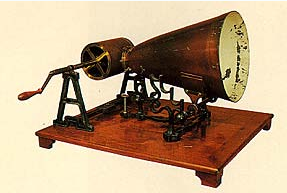


2008-20….

Special studies

Web site: http://irene.lbl.gov/

History



- 1859 Leon Scott: *Phonoautograph* paper recorder
- 1877 Thomas Edison invents sound reproduction

  on tin foil *Phonograph*

Discos fonográficos Pathé
Caras y Caretas (7/7/1906)

- 1885 Bell and Tainter introduce wax cylinder
- 1887 Emile Berliner commercializes disc *Gramophone*
- 1925 Western Electric *Orthophonic* (electrical) system

  end of the "**Acoustic Era**"

- 1929 Edison production ends, lacquer transcription disc introduced
- 1947 Magnetic tape in production use, Ampex 200A

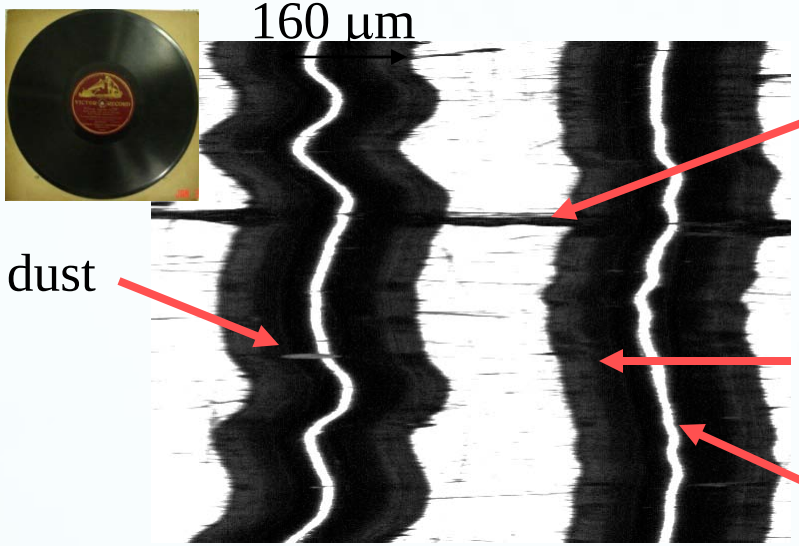
- 1948 33 1/3 rpm LP introduced
- 1958 Stereophonic LP on sale, uses 45/45 system
- 1963 Cassette magnetic tapes

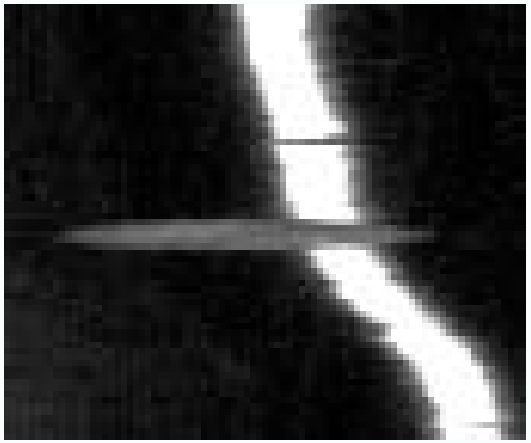
- 1982 Compact Disc (*CD*)

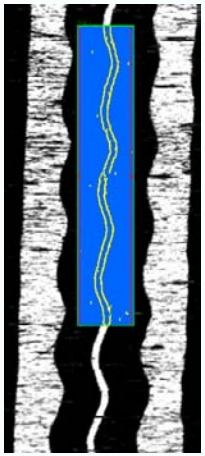
  end of the "**Analog Era**"

- 2001 Apple *IPOD*

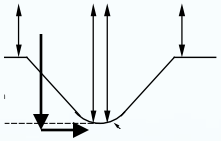
2D Imaging: Electronic Camera



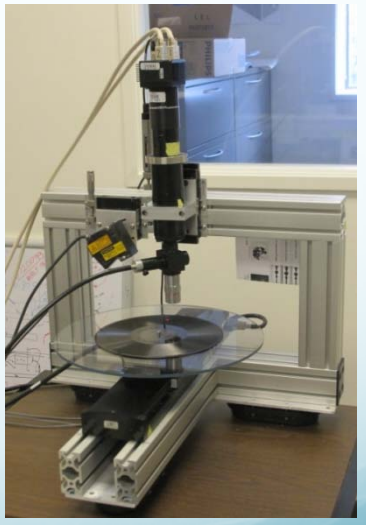




Coaxial illumination



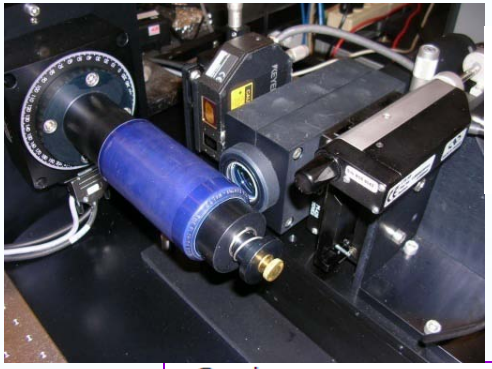
- Suitable for disc with lateral groove
- Require 1 pixel = ~ 1 micron on the disc surface
- High resolution yields narrow depth of field, 10 – 20 microns
- High speed cameras allow near “real-time” imaging
- Extract groove information from high contrast edge transitions

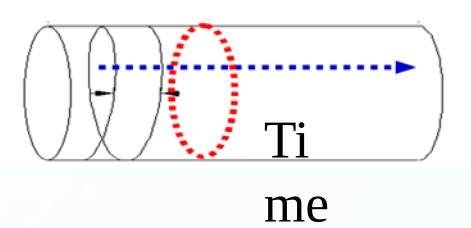


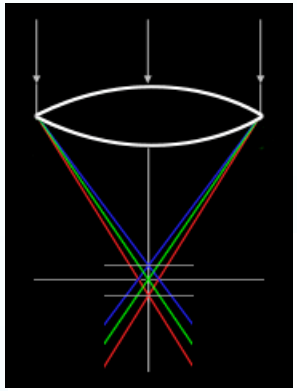
“IRENE”

3D Imaging: Confocal Scanning Probe

Required for cylinder with vertical groove modulation.







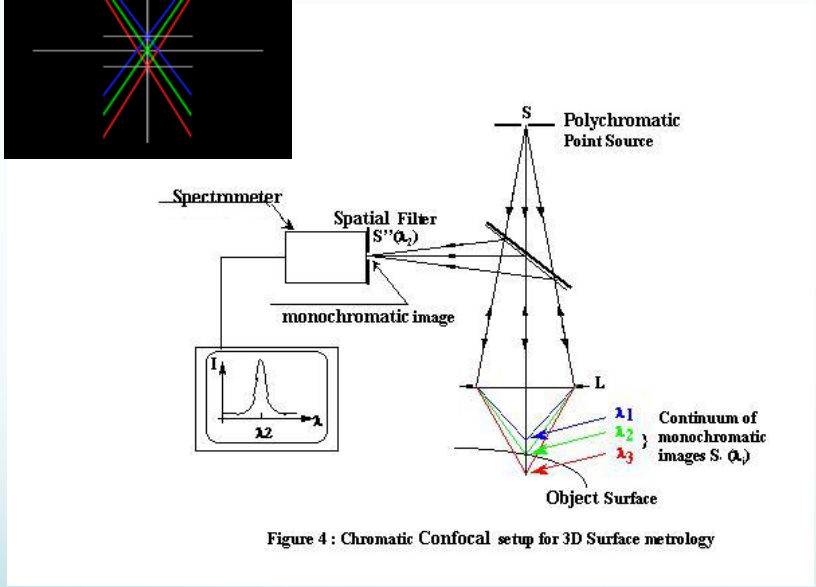
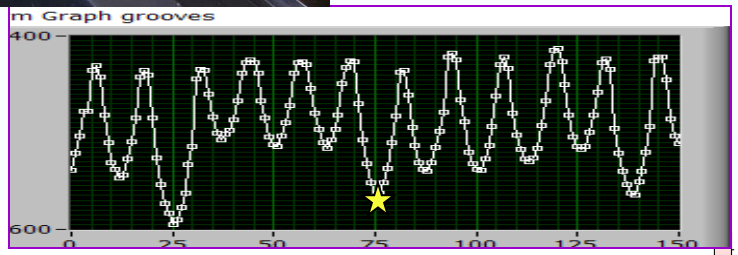
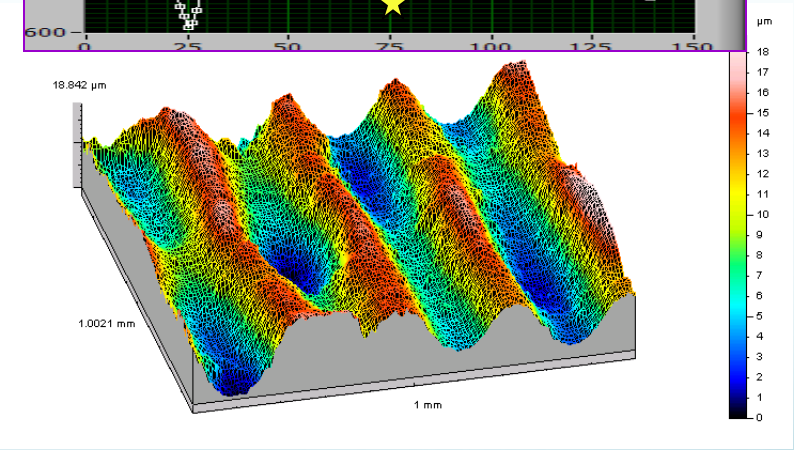


Figure 4 : Chromatic Confocal setup for 3D Surface metrology





Capable of scanning a cylinder in 20-80 min.