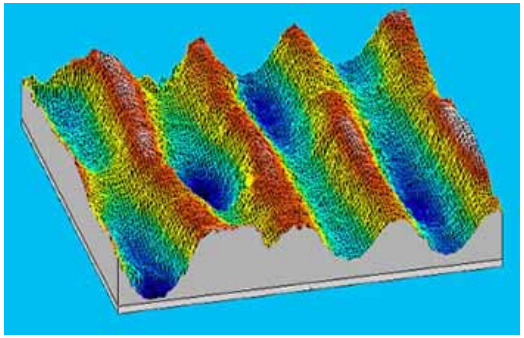
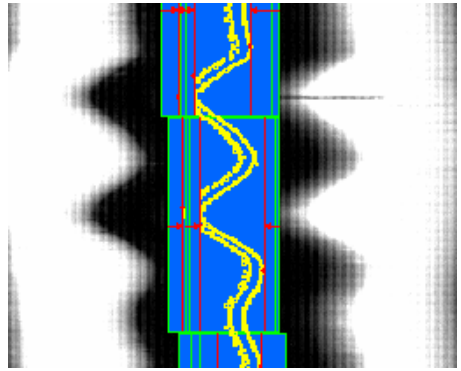




New Imaging Methods to Restore Historical Sound Recordings

Carl Haber
Lawrence Berkeley National Lab

Lawrence Berkeley National Lab

www.lbl.gov

- Founded in 1931 by E.O.Lawrence
- Oldest of US National Labs
- Operated by the University of California for the US Dept of Energy
- 4000 Staff, 800 Students, 2000 Guests
- 14 Research Divisions including
  - Physics, Nuclear Science
  - Materials, Chemical Science
  - Life Sciences, Physical Bioscience
  - Energy and Environment, Earth
  - Computing
- Major user facilities-
  - Advanced Light Source
  - Nat. Center for Electron Microscopy
  - Nat. Energy Research Super Computer Center
  - Joint Genome Institute
  - Molecular Foundry

Collaboration and Support

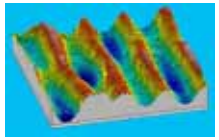
Lawrence Berkeley National Lab
The Library of Congress

University of Southampton, U.K
EIF Fribourg, Switzerland

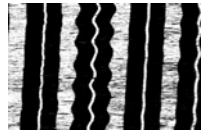
Support from
Library of Congress,
National Endowment for the Humanities,
A.P. Mellon Foundation,
National Archives
J.S. Guggenheim Memorial Foundation,
Department of Energy

Introduction

- We are developing methods of optically recovering mechanical sound recordings **without contact** to the media.
- Address concerns of the preservation, archival, and research communities:
  - Preservation: The reconstruction of delicate or damaged media
  - Access: Mass digitization of diverse media
- The approach evolved naturally out of methods of optical metrology, pattern recognition, and image processing.



Non-Contact Digital Imaging



- Create high resolution digital map of entire surface
- Computer plays record (image) with a virtual stylus
- Product
  - Standard digital sound files (ie .wav)
  - High resolution digital images which may be reanalyzed later as well
- Protects samples from further damage
- Repair existing damage through “touch-up”
- Reconstruct broken records
- Offload aspects of restoration to automated software

A “smart” copying machine for records

Status and Questions

- Basic technology has been demonstrated and studied on a range of media over past 4 years.
- A phonograph disc record scanner has been built and is now under evaluation here.
- Want to understand the future directions for this research and its development.
- Recognize that early 20th century ethnographic fieldwork is a significant component of the historical archive. Do these method have any role to play there?

History

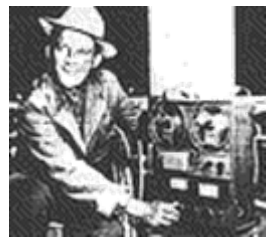
- 1859 Leon Scott: *Phonoautograph* paper recorder
- 1877 Thomas Edison invents sound reproduction on tin foil *Phonograph*

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

end of the "**Acoustic Era**"

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

- 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*)

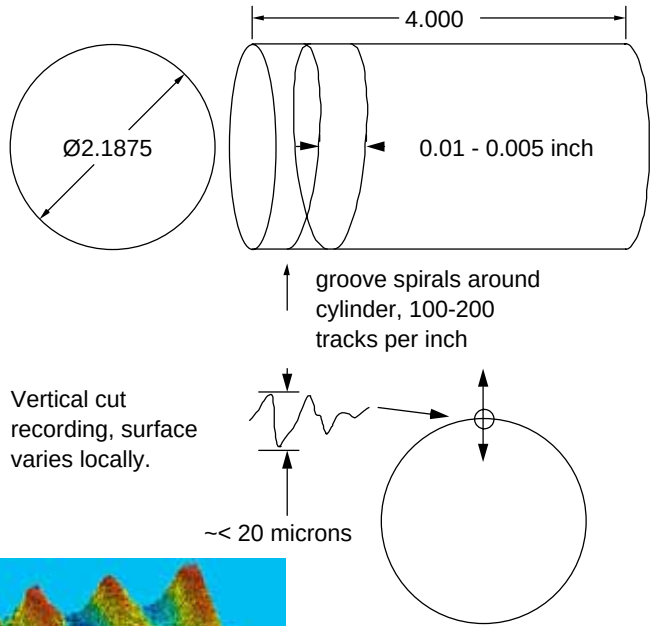
end of the "**Analog Era**"

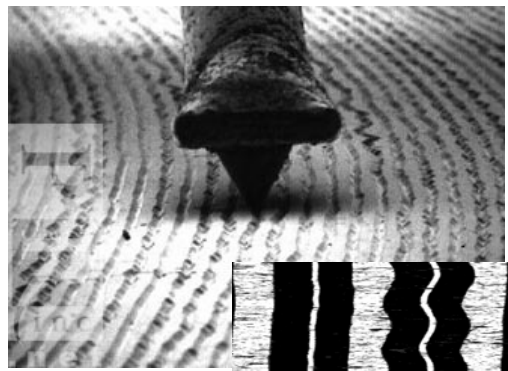
- 2001 Apple *IPOD*

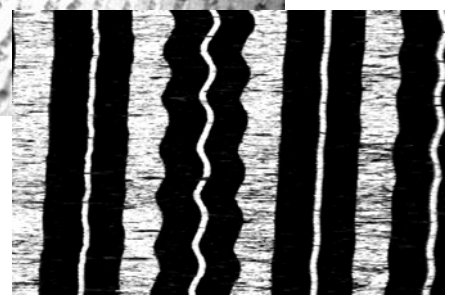
Mechanical Recording Principles

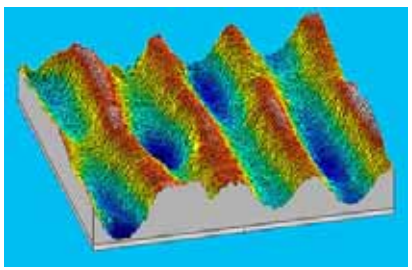
Cylinder: groove varies in depth (Vertical Cut)

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









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

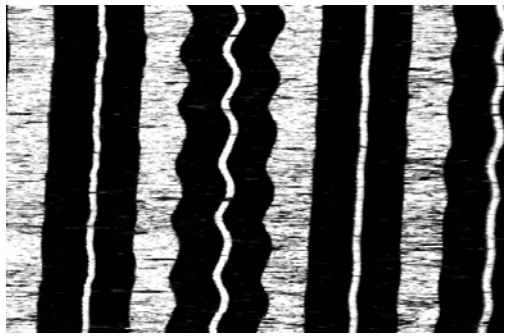
Diverse media

Shellac disc (“78”): main commercial media before vinyl (1950’s), scratches, wear, breakage

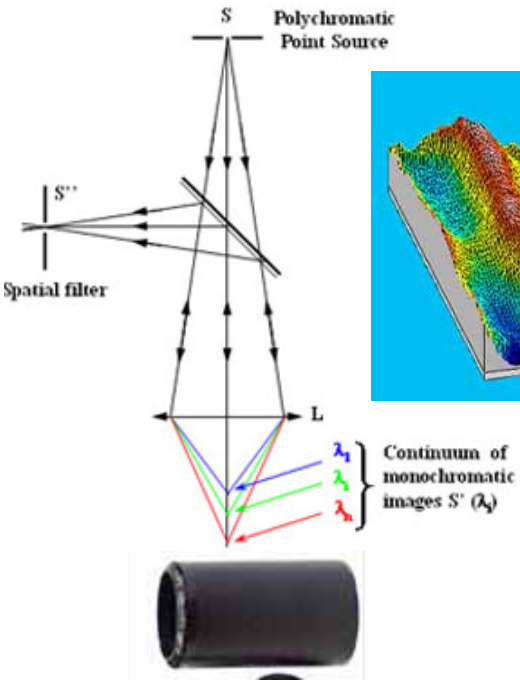
Lacquer, Al disc: instantaneous records pre-tape (~1948) exudation, flaking

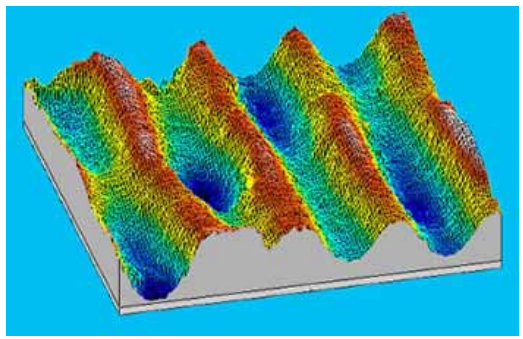
Wax and plastic cylinders: mold growth, wear, breakage

Plastic belts: dictation, monitoring (1940’s-60’s), folds, cracks, wear



2D Imaging
- Digital photography
- Limited information
- Fast





3D Imaging
- Requires confocal scanning microscopy
- Full profile is measured
- Slow

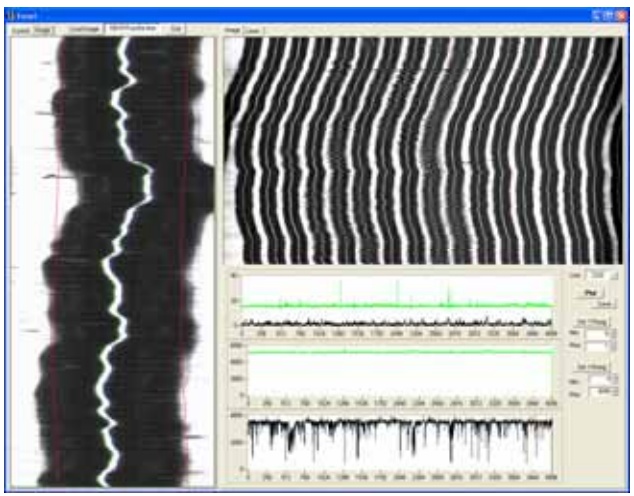
Projects Underway

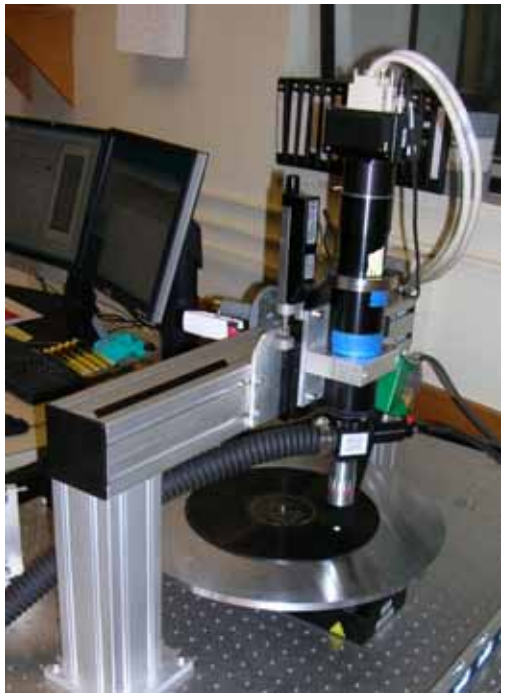
- Concept was tested 2002-2003 leading to interest and support from the Library of Congress and others.
- IRENE: a fast 2D optical scanner for disc records
  - Digital access to the most common media + special formats
  - Installed at the Library of Congress 8/2006
- 3D scans on “Edison” cylinders
  - Preservation and restoration of early and damaged recordings
  - R&D with the Library of Congress and special projects
- 3D scans on plastic dictation belts
  - Feasibility study for preservation transfers of damaged media

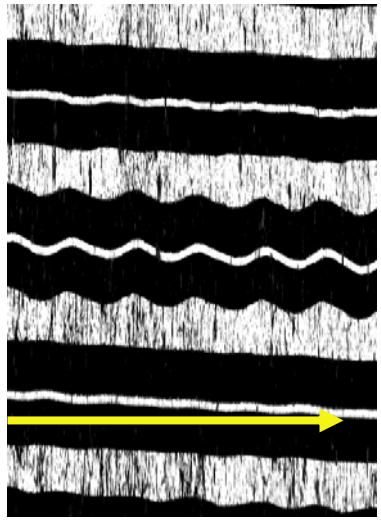
I.R.E.N.E.

Image, **R**econstruct, **E**rase **N**oise, **E**tc

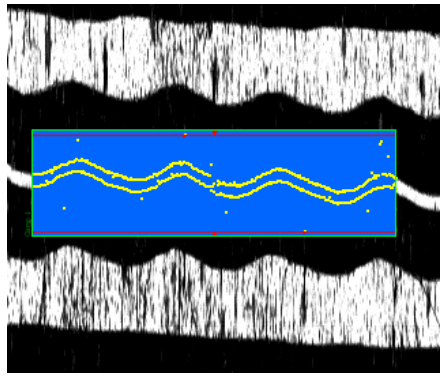
- Funded by NEH in 2005, installed at Library of Congress 8/2006
- 1 year development and construction
- Experimental “production” machine and test-bed for future development
- Emphasize throughput and diversity (access), scan time ~10-15 minutes
- Provide statistical measures of media
- Currently under evaluation



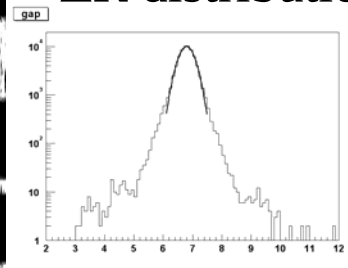




Time
Pixels = 104 KHz

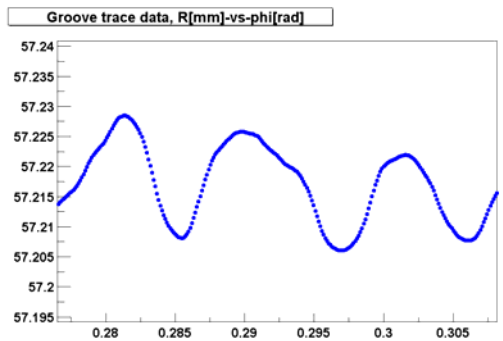


ΔR distribution

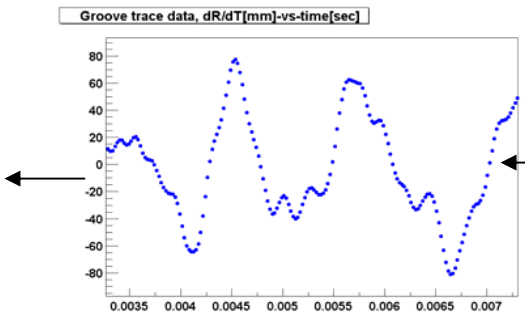


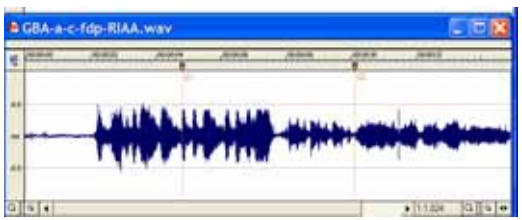
Width across groove bottom

Measure slope at each point (stylus velocity)



Average
Filter using ΔR<cut



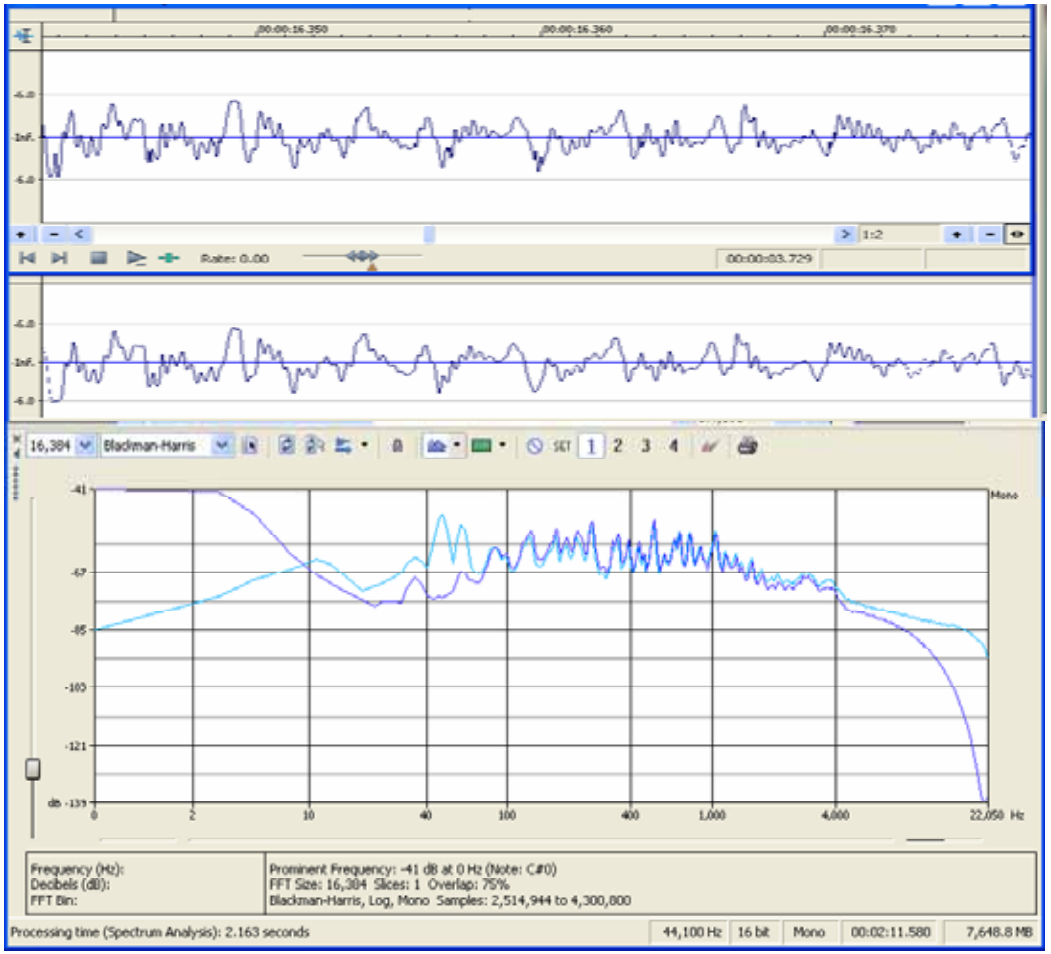


Example of IRENE playback on a pristine acetate disc

The following slides compare playback on various discs between a stylus and IRENE. The selections span a range of conditions and materials.

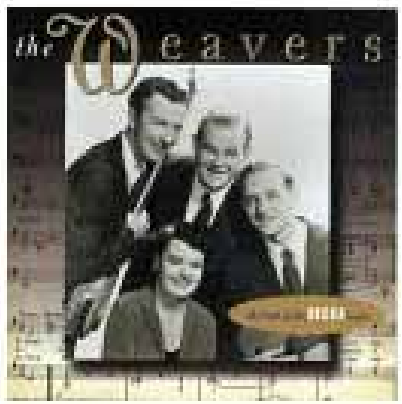
These results are preliminary

Goodnight Irene: Weavers 1950
late model electrically recorded shellac disc

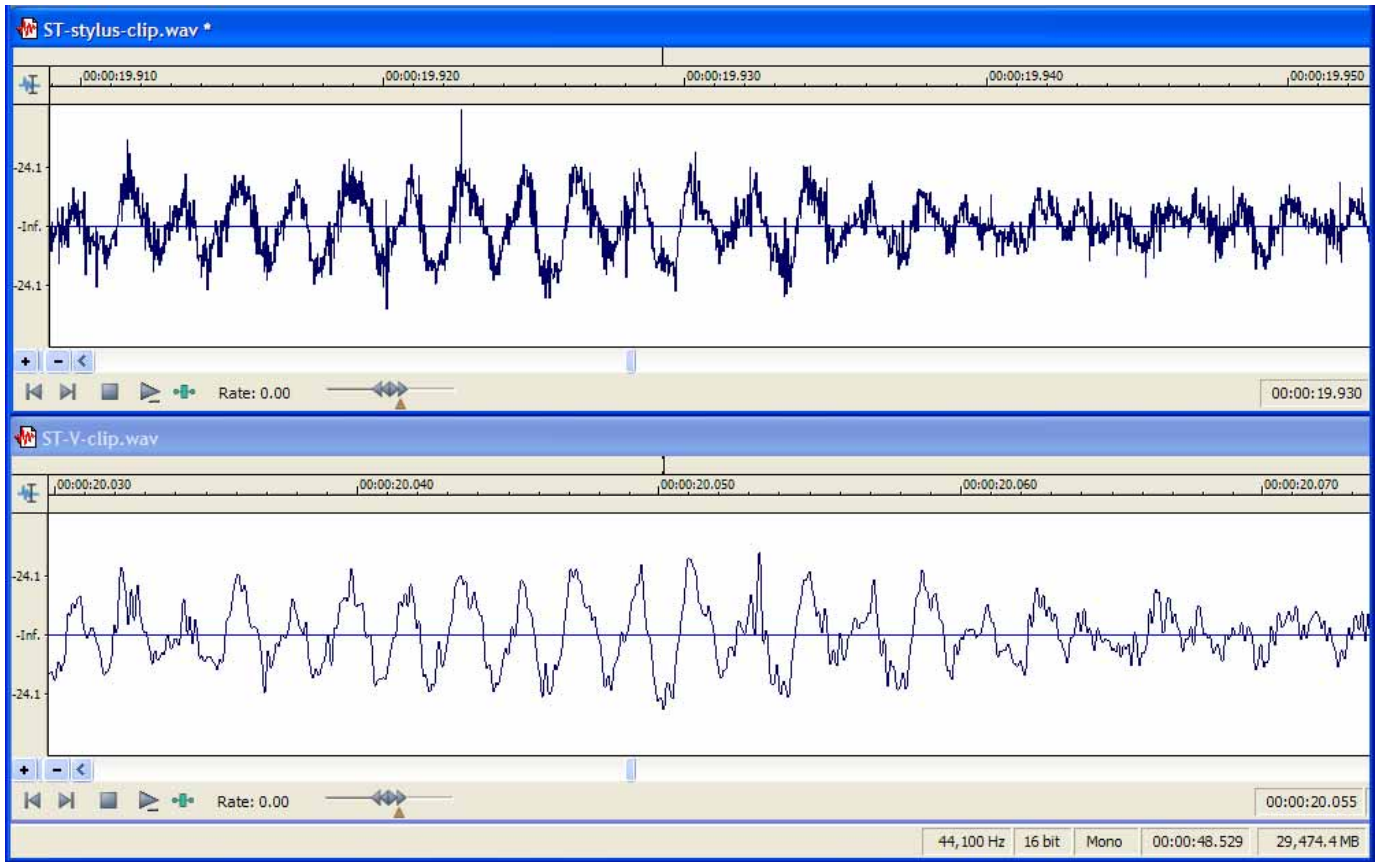


stylus

IRENE



Silver Threads Among the Gold:
Elsie Baker 1913 Victor 17474-A
Early, acoustically recorded, shellac disc



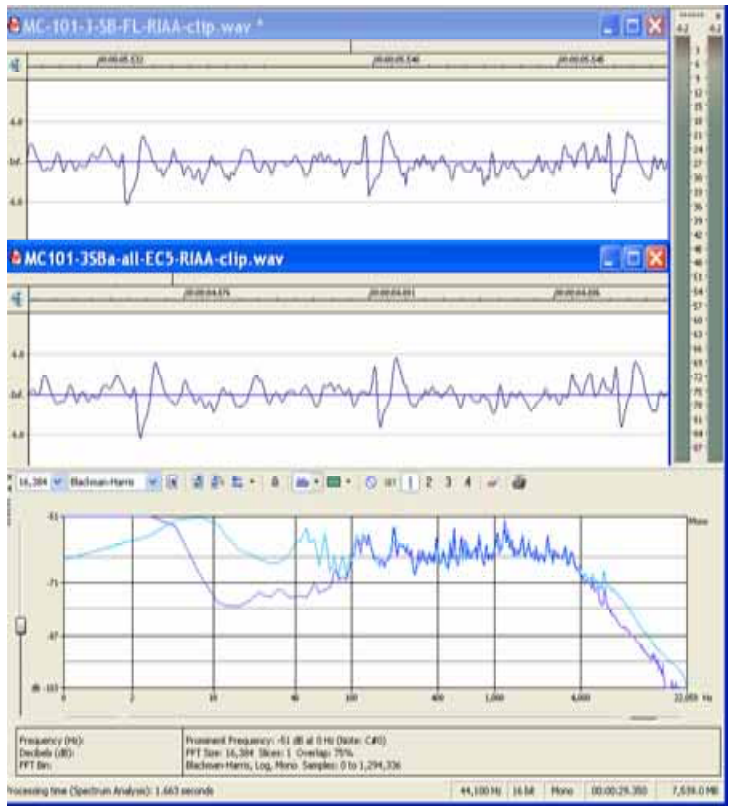
stylus

IRENE

Studio Test 1947 Cellulose Acetate

Mutt Carey and his New Yorkers: Shim-Me-Sha-Wabble

Lacquer disc, RIAA EQ



stylus

IRENE

Spoken Word Lacquer Discs

78 rpm acetate,
Theos Bernard,
interview, 1929

U. S. Tibetan Scholar Is Missing In Punjab After a Tribal Attack

Theos Bernard, Author, Feared Dead by Wife Who Reports Incident in New Delhi

NEW DELHI, Oct. 30 (AP)—An American student of Tibetan culture has been missing since mid-September on a trip to a Tibetan monastery and may be dead, his wife said today.

He is Theos Bernard, 40, of New York and Santa Barbara, Calif., son of G. A. Bernard of Northridge, Calif.

Interviewed here, Mrs. Bernard said shepherds had told of seeing Lahouli tribesmen attack her husband's party and kill his Moslem servants. That was in the Himalaya Mountains of northern India, she said, between Sept. 12 and Sept. 16.

Mrs. Bernard said she had learned that her husband then was short of food and she feared that he might also have lost his heavy clothing to the raiders.

Mr. Bernard set out Aug. 20 from the out-of-the-way Kulu Valley of the northern Punjab. Six days after that, she said, Hindu-Moslem rioting broke out in the valley and she herself had to flee 126 miles on foot southward to Simla. She passed through New Delhi today on her way to Calcutta, where she said she would await word of her husband.

Theos Bernard

Oriental Philosophy from Colum-

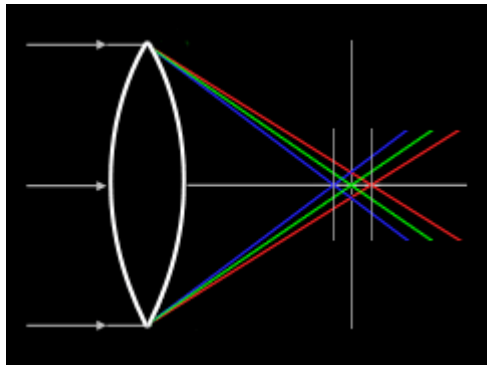
Testing and Validation Phase

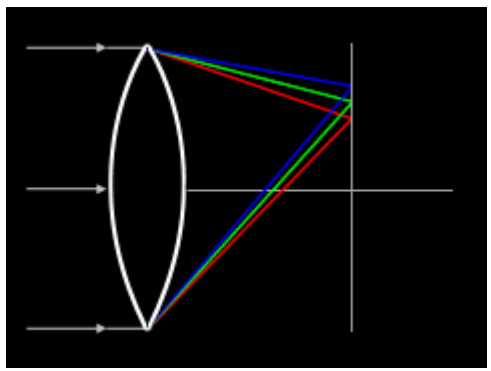
- 9-12 months in duration in the LC Recording Lab
- Led by Peter Alyea
- Machine to be tested on a significant sample of media
  - Quantitative comparisons with test (& other) records
  - Variety of media types and condition
  - Listening tests
  - Flat and historical EQ's
  - Study scan parameters and analysis/reconstruction options
- Results to be documented and disseminated
- Possibility of a follow-on stage
  - Upgrades to software and/or hardware
  - Expanded media study

Cylinder Scans

- Cylinder History 1877 –1930 (approx)
  - 1877 Aluminum foil
  - 1885 Soft wax for original recordings, fieldwork. and dictation
  - 1902 Hard wax molded, commercial
  - 1908 Cellulose molded, commercial “Amberols”

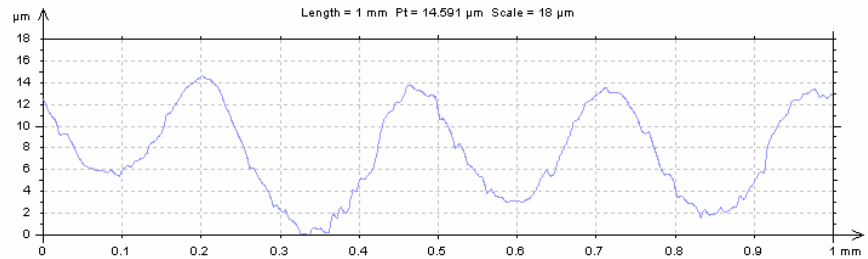
Chromatic Aberration

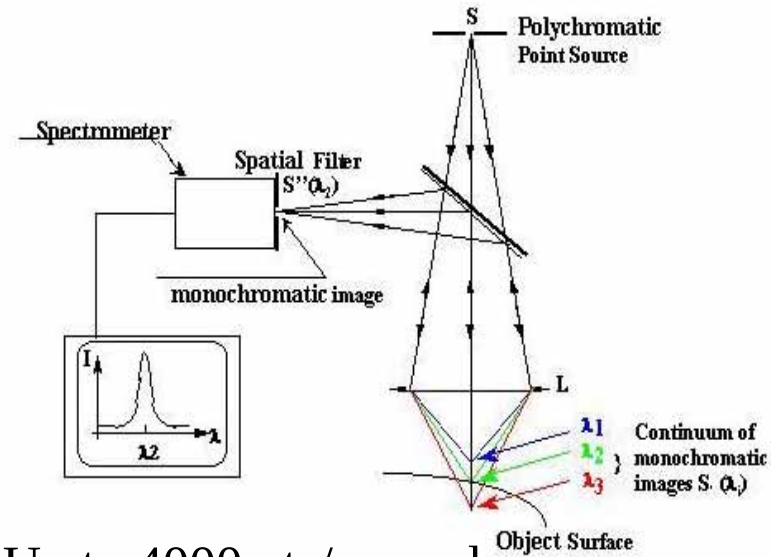


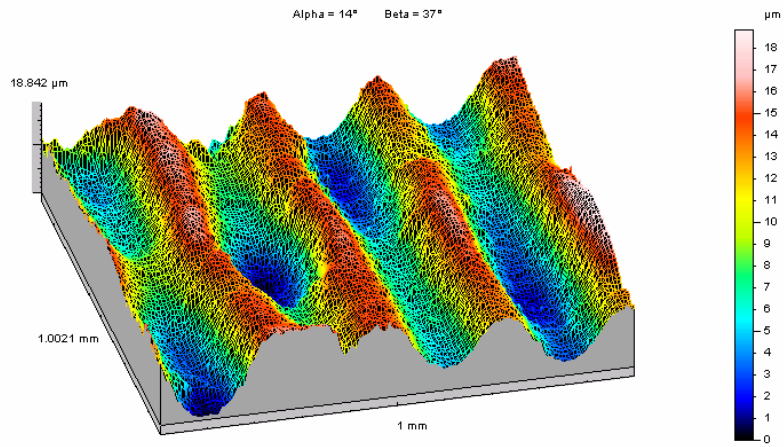


3D Imaging: Confocal Scanning Probe

Required for cylinder with vertical groove modulation.



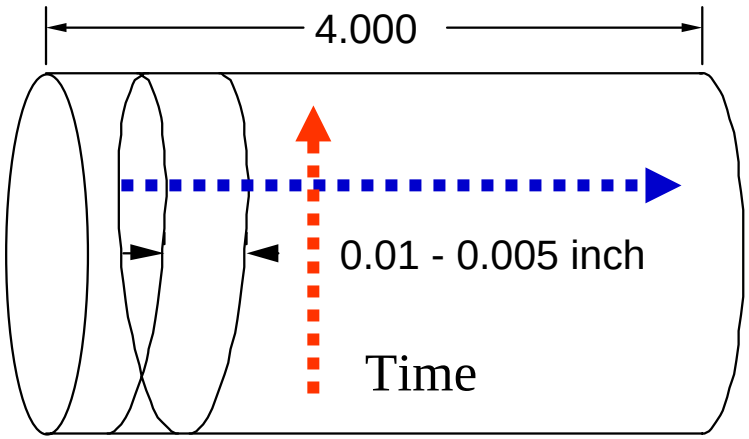


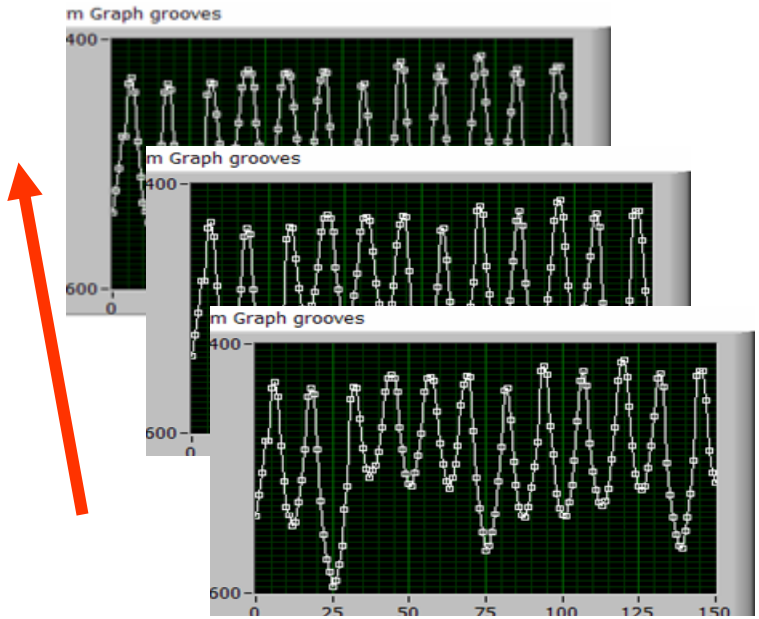


Up to 4000 pts/second
~ 5 micron point size

Surface of an Edison cylinder

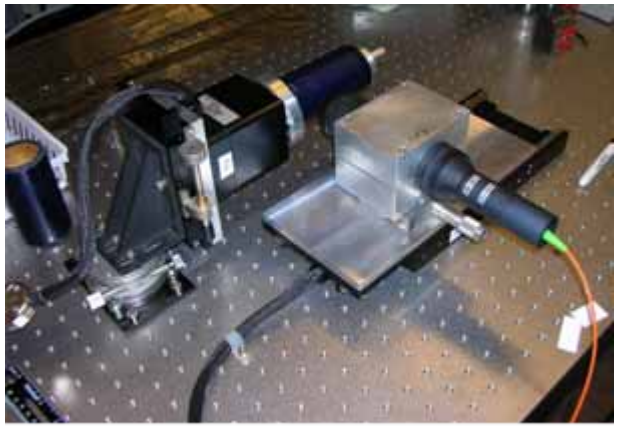
Speed and Data

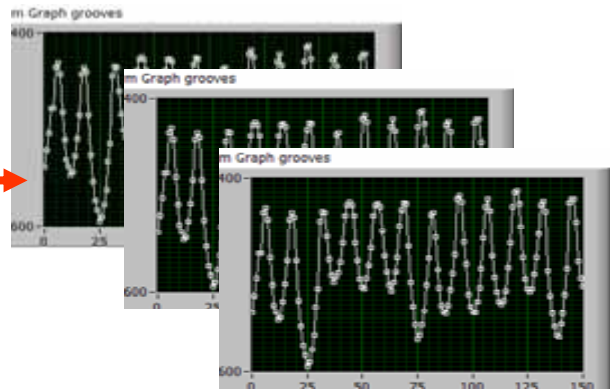


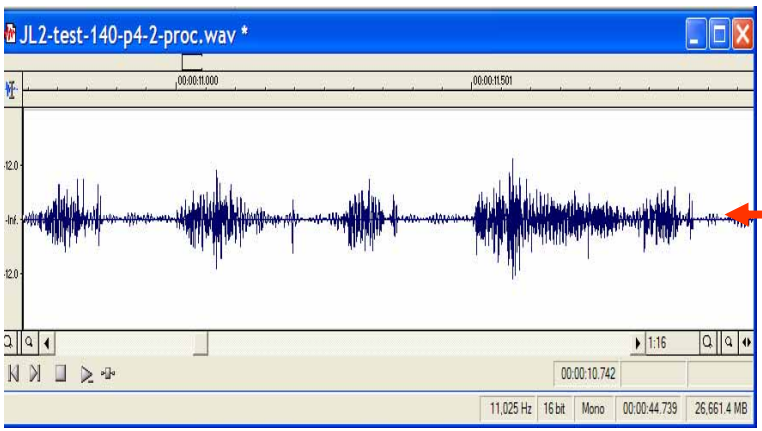


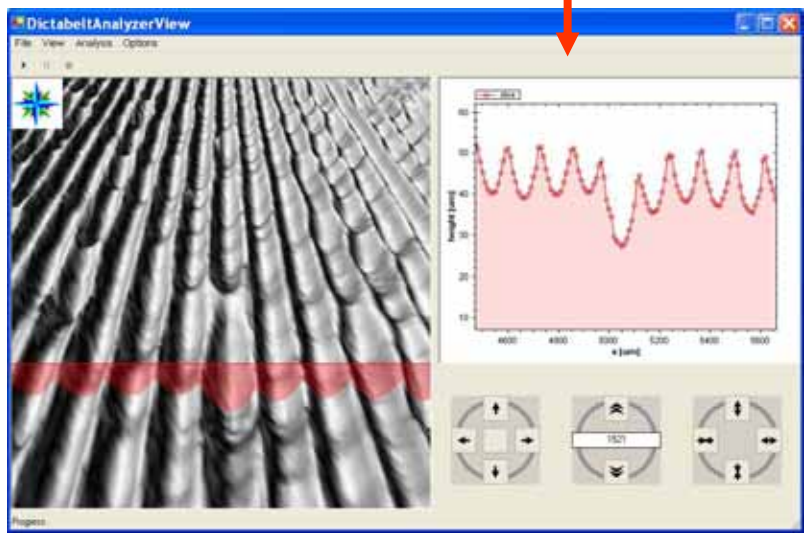
- Point by point measurement
- Exposure time per point
- Grid along time direction (red) = digital sampling
- Grid along axis direction (blue) = points per profile
- Number of probes = cost ($)
- 1 probe, 48 KHz ~ 80 hours
- 4 probes, 12 KHz ~ 6 hours

EDISON
GOLD MOULD
RECORDS
ECHO ALL
OVER THE WORLD

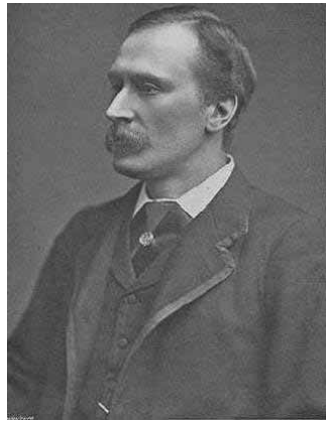



m Graph grooves
m Graph grooves
m Graph grooves


JL2-test-140-p4-2-proc.wav *
00:00:11.000
00:00:11.501
1:16
00:00:10.742
11,025 Hz
16 bit
Mono
00:00:44.739
26,661.4 MB


DictabeltAnalyzerView

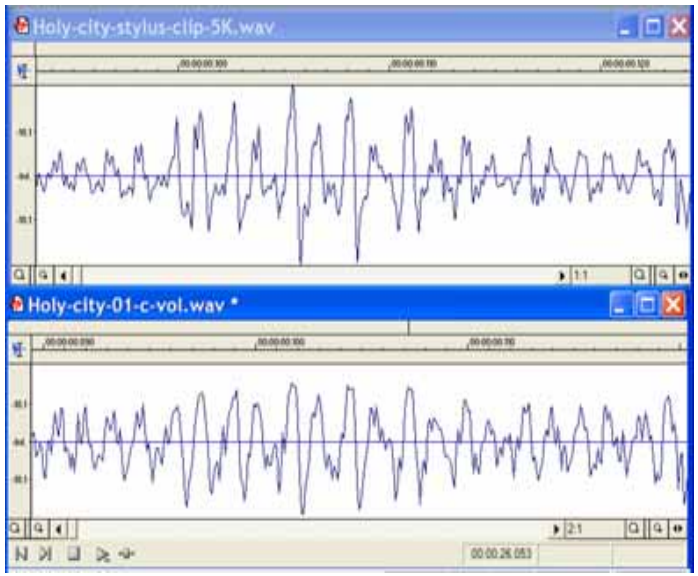
Sound Comparison



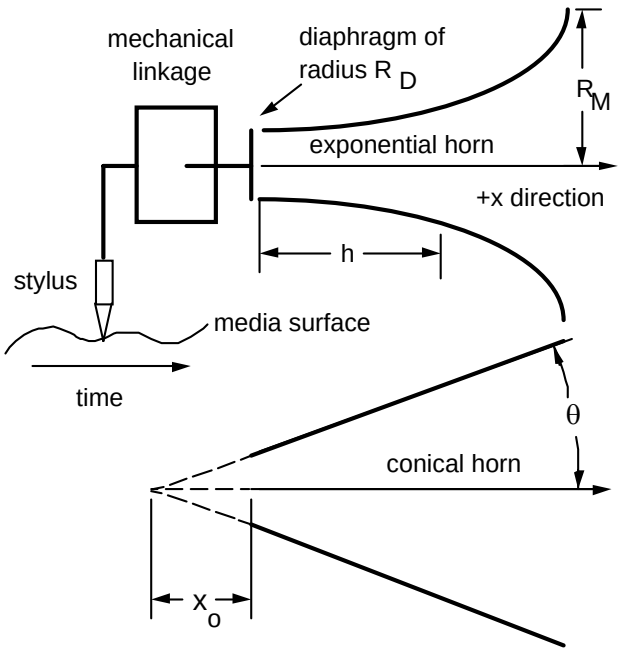
- The Holy City, composed by Stephen Adams,

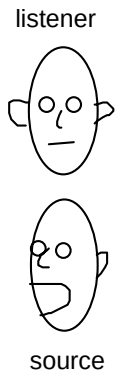
  The Edison and Skedden Mixed Quartet, Amberol 1601

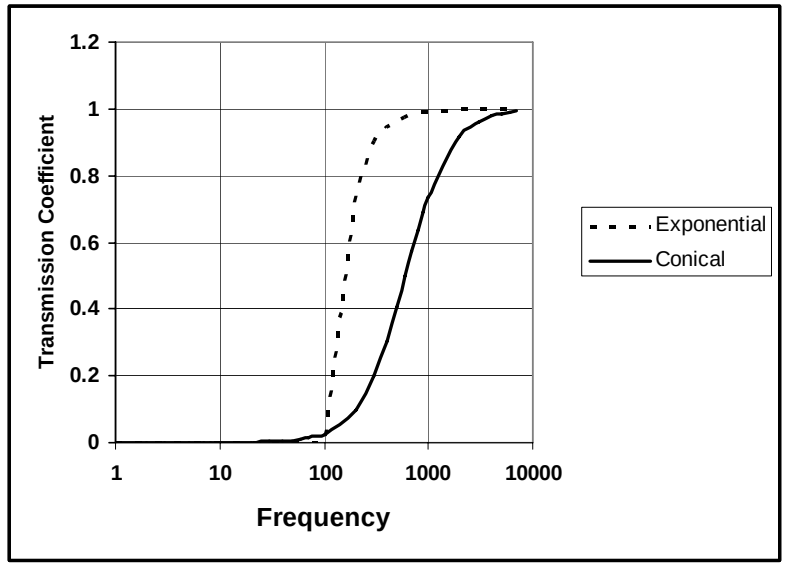
  Commercial cellulose release



- Stylus
- Optical
- Optical + filter + EQ



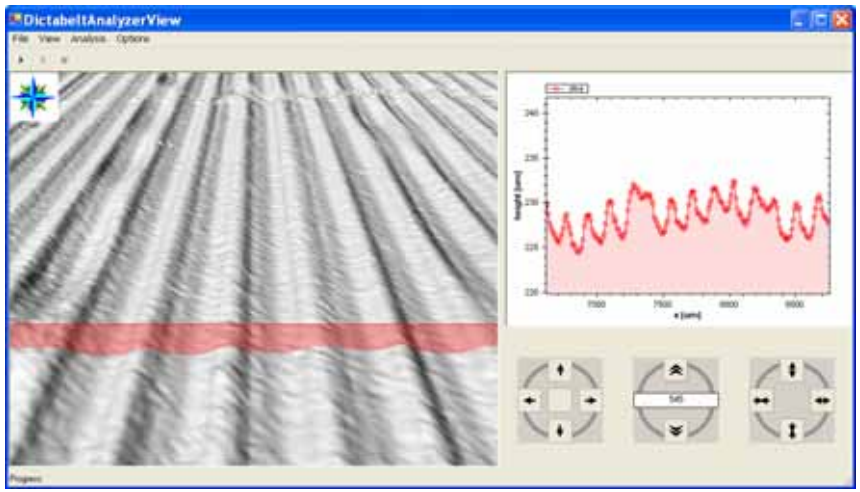


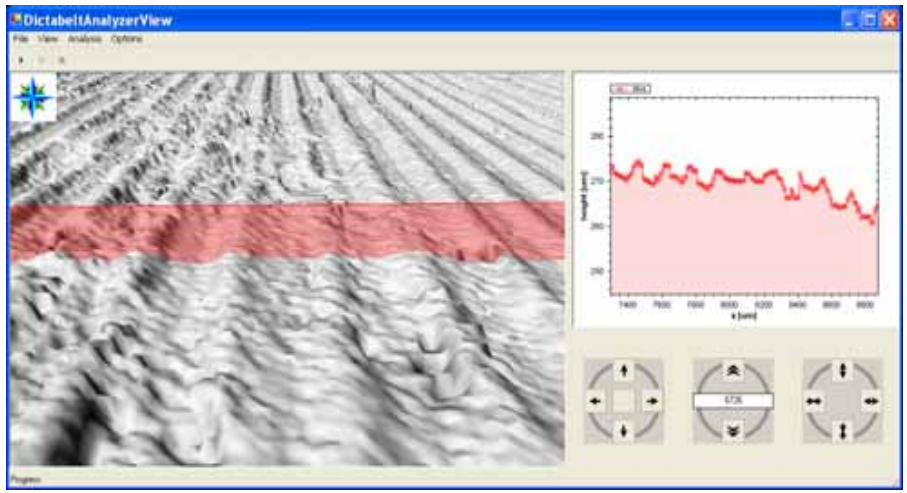


Response of horn and diaphragm at low frequency can modify response and deviations from “constant velocity” characteristic.

Surface Damage = Sound Degradation

- Fungus growth on wax cylinders destroys the surface
- Recrystallization alters surface texture
- Impacts unique samples – early recordings, field work, dictation

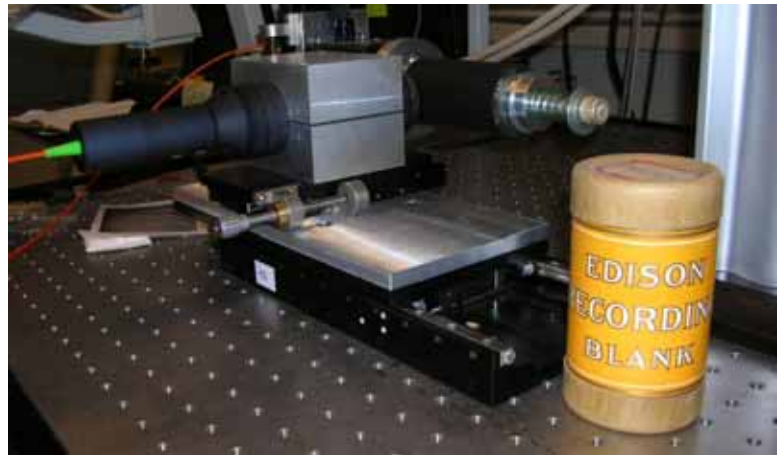




A research priority for the Library of Congress and a focus of our on-going effort

UC Berkeley Phoebe Hearst Museum holds an extensive collection of wax cylinders recorded by Anthropologist Alfred Kroeber and others. This sample is from the set recorded of Ishi (circa 1911-14).

Sam Batwai, Alfred L. Kroeber, and Ishi



Ishi at Deer Creek

Prospects

- Disc scanning (IRENE) is under evaluation at the Library of Congress now.
  - Speed is practical for large scale projects (many discs/day)
  - Can address damaged or delicate disc media
  - Signal quality, noise, algorithms under study
- Cylinder (3D) scanning is an R&D effort at present.
  - How should it moved into practical use?
  - Speed will likely remain limited to 1-3 items/day per system. Depends also on certain tradeoffs.
  - Can certainly be used to target specific items/collections and special projects.

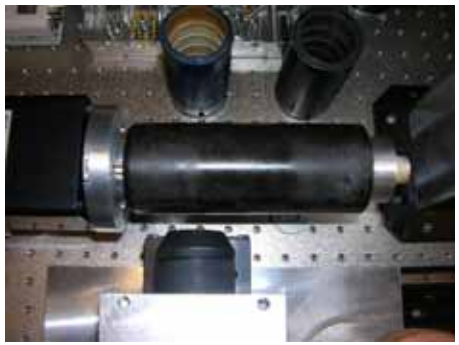
Native American Collections
(partial list)

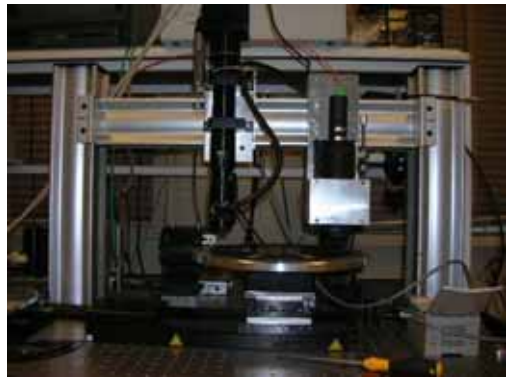
- Library of Congress
  - Omaha Indian Music: collected by Alice Fletcher and Francis La Flesche ~1897—99
  - Francis Densmore recordings
  - ~8500 cylinders
- National Anthropological Archives
- Indiana Univ. Archives of Traditional Music,
  - Collection spans 1893—1938, ~6000 cylinders
- UC Berkeley Phoebe Hearst Museum
  - recordings by A.Kroeber and others, >3000 items
  - Linguistics collections
- University of Washington Libraries
  - Pacific Northwest Native American Materials in the Melville Jacobs Collection (and others)

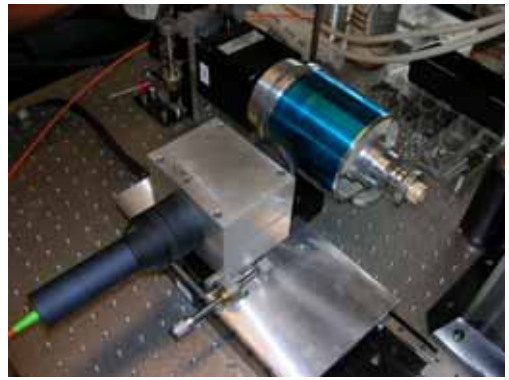
Questions

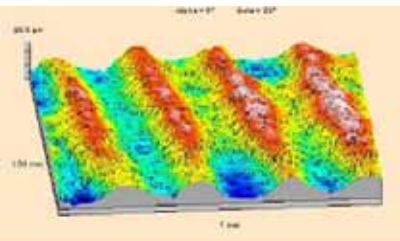
- Is access to these collections significantly limited by the lack of, or condition of, existing transcriptions?
- What is the general physical state of these cylinders?
- Are there important cylinders which have just been considered unplayable?
- Would there be interest in the community for greater or improved access to these recordings?
- What would be the criteria for determining the required quality or parameters of new transcriptions?

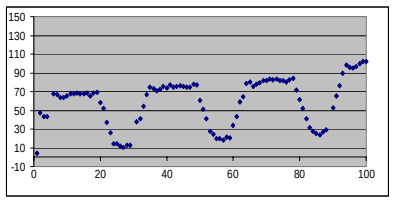
Optical Scanning: A general tool to preserve and create access to recorded sound history

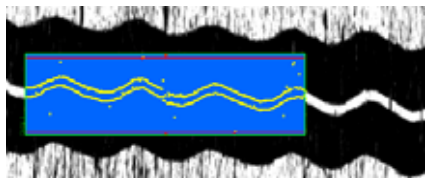












Wax cylinder

Shellac disc

Plastic dictation belt

Web site URL: irene.lbl.gov