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School of Engineering Sciences

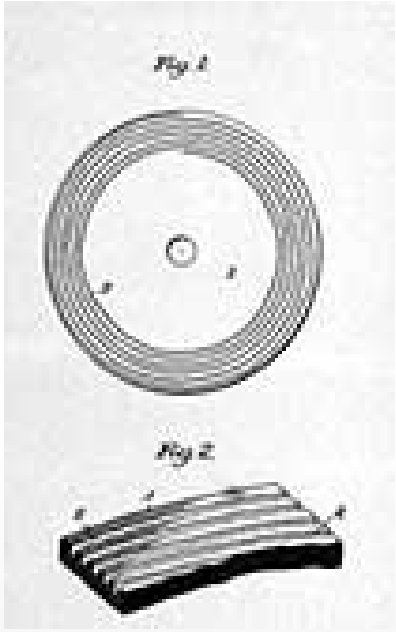
The Sound Archive Project 2005-2009

John McBride

Bristol, September 2009

Summary

- Introduction
- Overview
- Case Studies
  - Test Signal Cylinders
  - Evan Roberts Cylinder
  - Graphophone Cylinder (Queen Victoria)
  - Tinfoil Recording
  - Berliner Master.



Introduction

- Pre-2004. Early work undertaken in collaboration with TaiCaan Technologies Ltd.
- Need for depth measurement for vertically cut recordings.
- EPSRC funding awarded in 2004, for a 4 year programme, which commenced in March 2005.
- Aim was to provide a full digital map of recorded surfaces suitable for archival purposes.

The non-contact mapping method

- This is not real time playback
- The methods lead to highly detailed 3D maps of surfaces.
- The maps can then be used to generate the sound, or potentially in the near future to recreate the artefact.
- Damaged or dirty surfaces can be measured and then removed using processing methods in the spatial domain.
- A single system can be used for all flat disc surfaces, and another for all cylinder surfaces.
- Sound playback can be fully software controlled in post-processing.

How does this compare with real time playback

- Stylus: Cannot be used on broken or fragile surfaces.
- Stylus: Will generate noise associated with dirty surfaces, surface roughness, and poor mounting.
- Laser Trackers: Essentially similar to Stylus, except more prone to dirty surfaces.

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Overview of technology

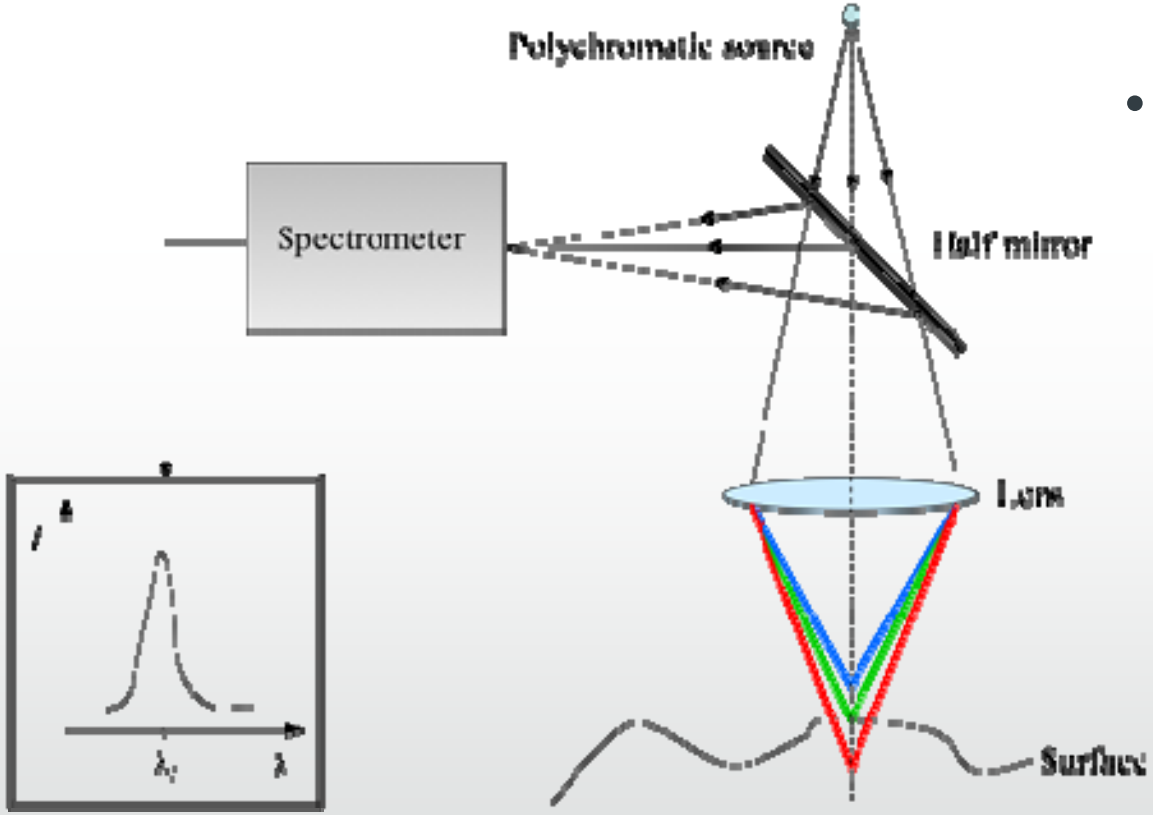
: www.archivesound.co.uk

Measurement Principles

Measurement Issues

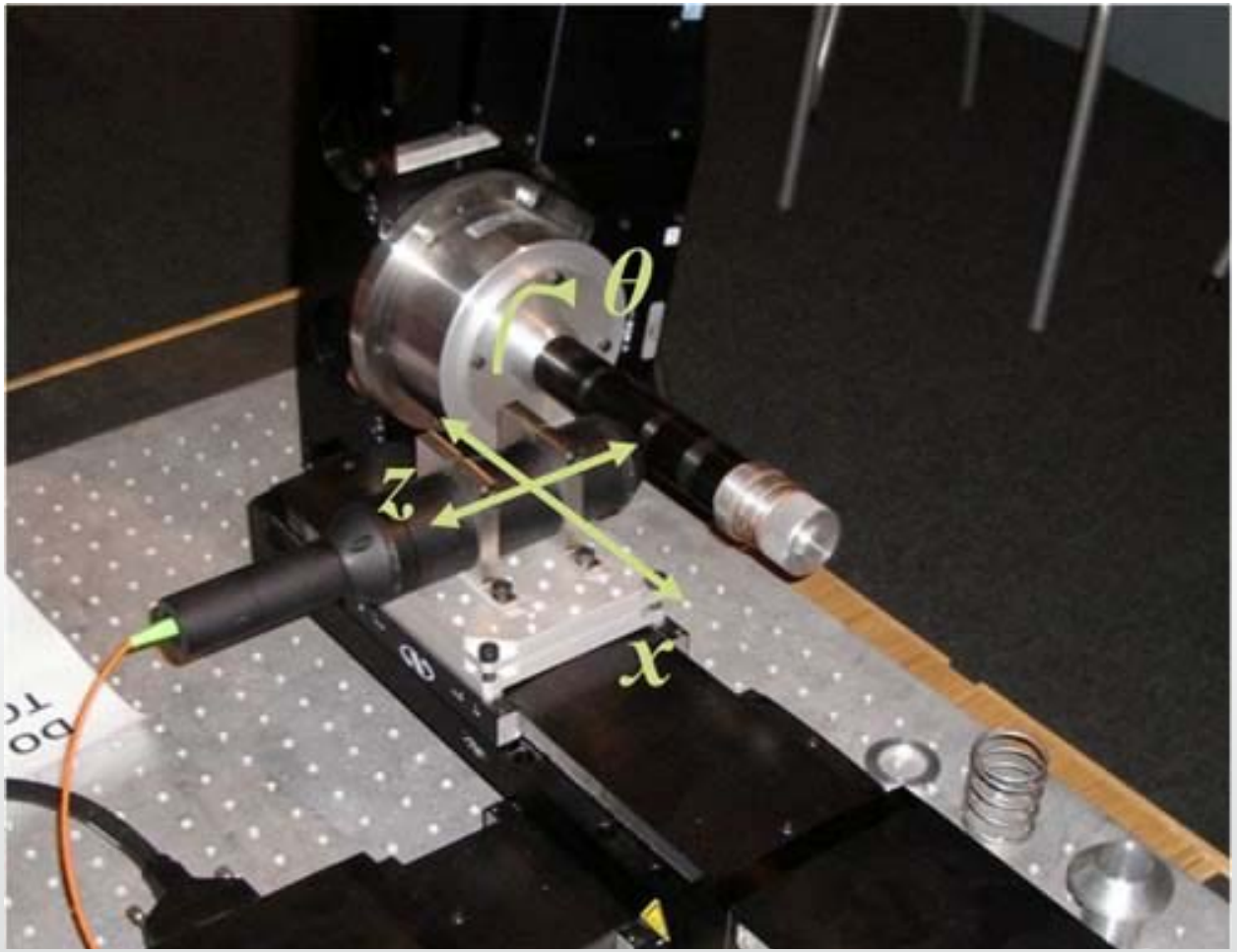
Audio Extraction

Non contact surface measurement

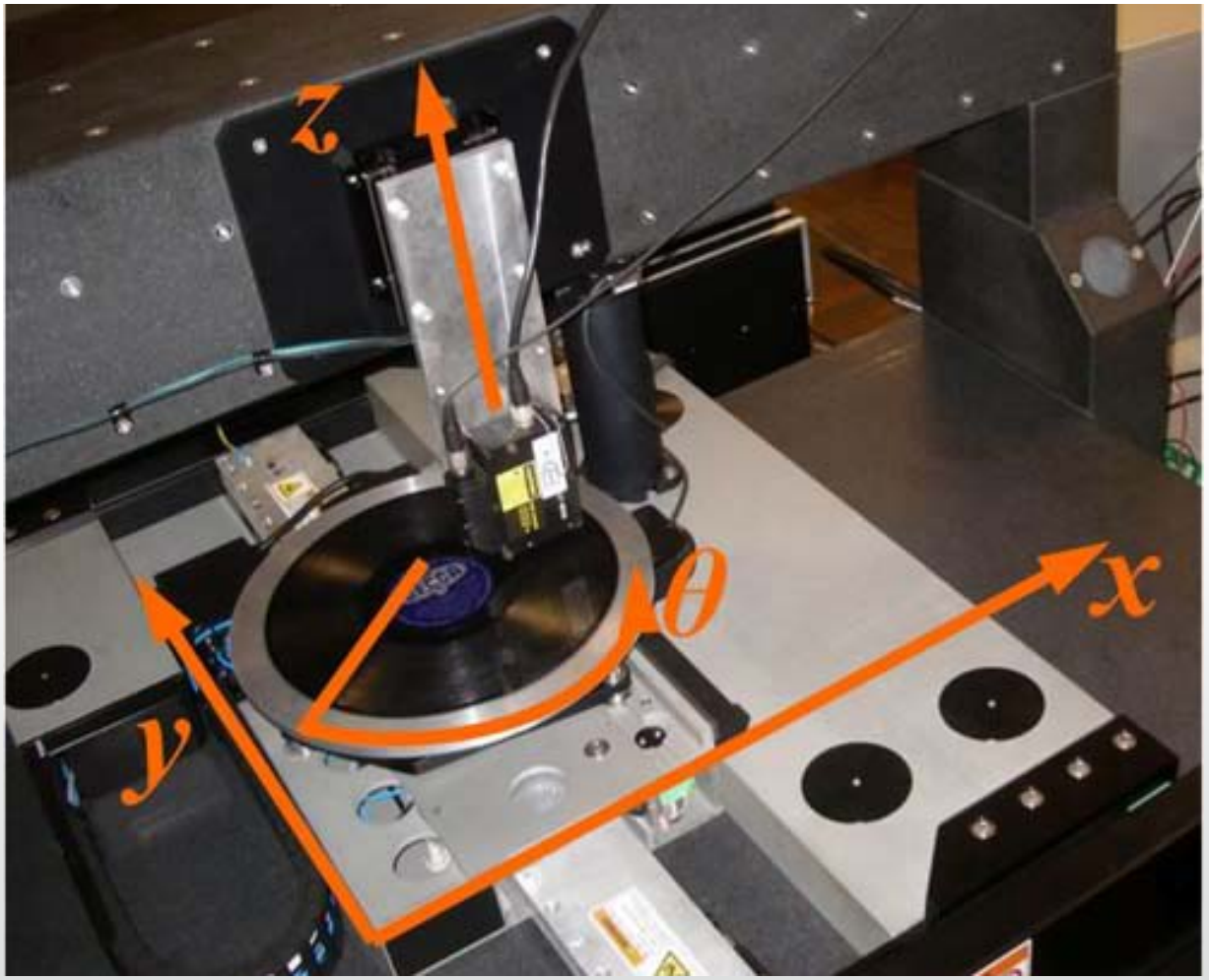


- White light confocal
- Also investigated
  - Laser confocal
  - Laser triangulation

Cylinder Scanning



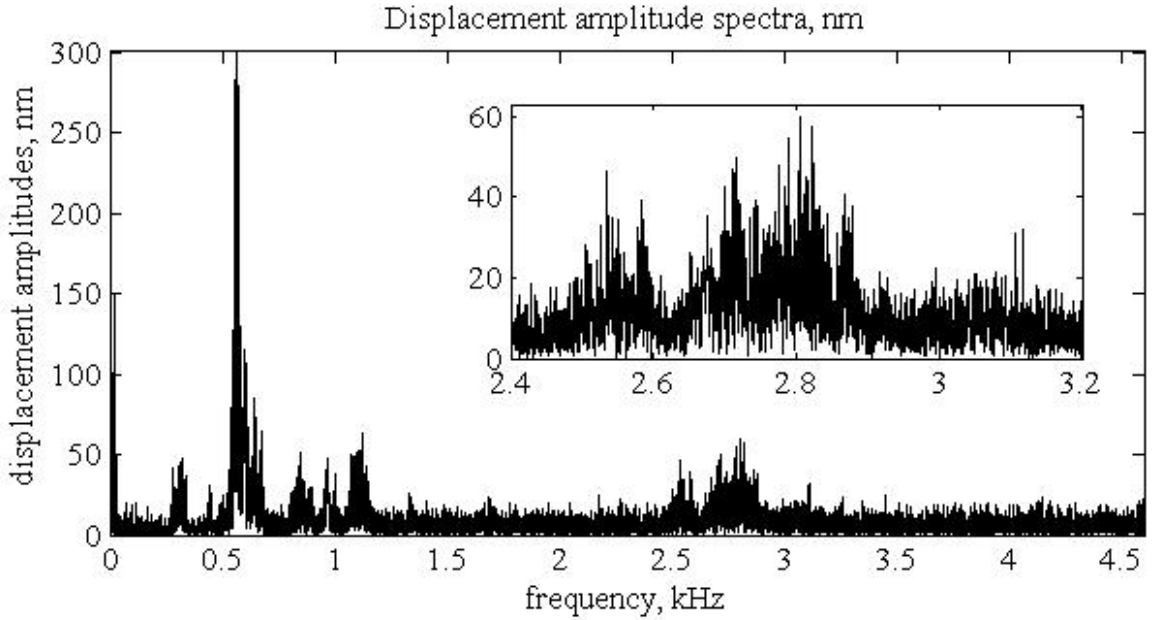
Disc scanning



Measurement Issues:

- Resolution
- Measurement range
- Angular tolerance
- Speed

Measurement Issues – Resolution



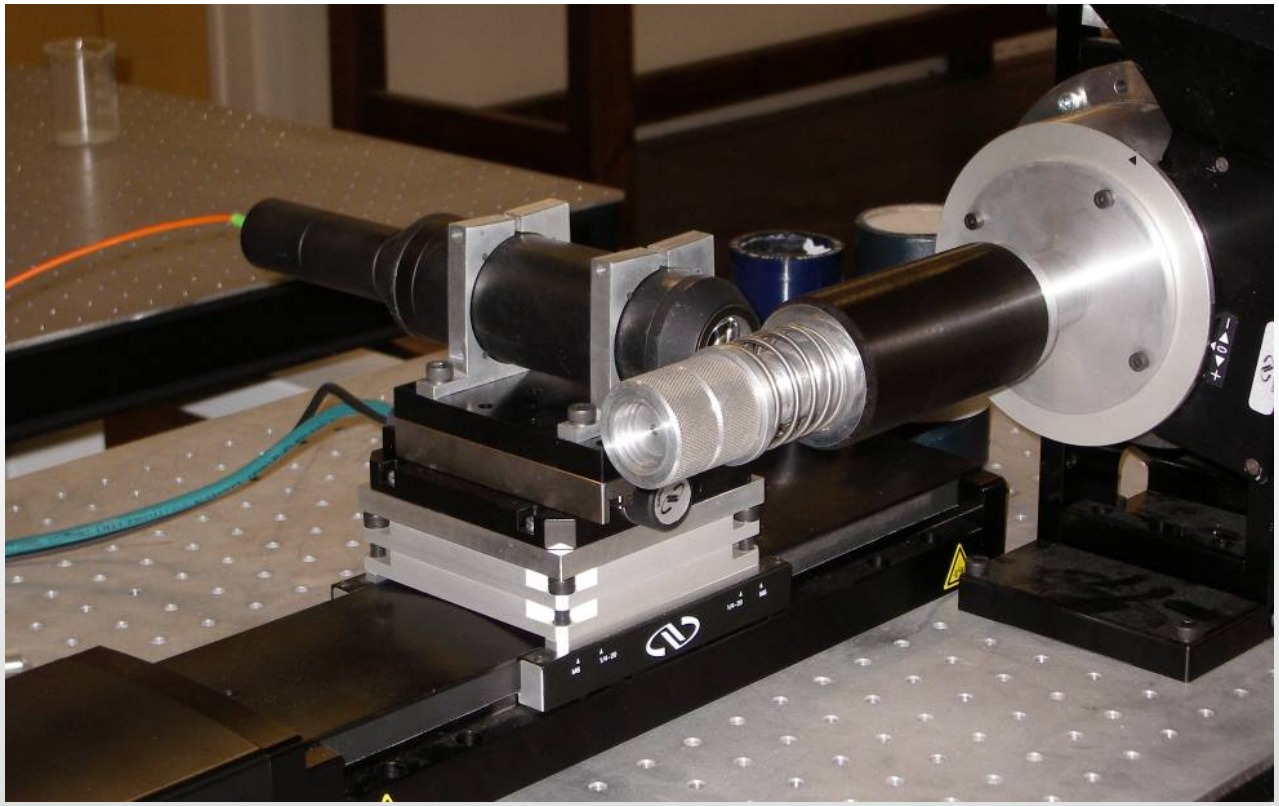
Spectrum of displacement data from a Blue Amberol cylinder.

Vocals in the 2.5-3.2kHz) are sub 50nm.

- Sensor selection - guided by requirement for at least 10nm vertical resolution

Measurement Issues – Resolution

- Need to match sensor z positioning sensor resolution to the 10nm resolution of the sensor itself



Cylinder system with 10nm stage

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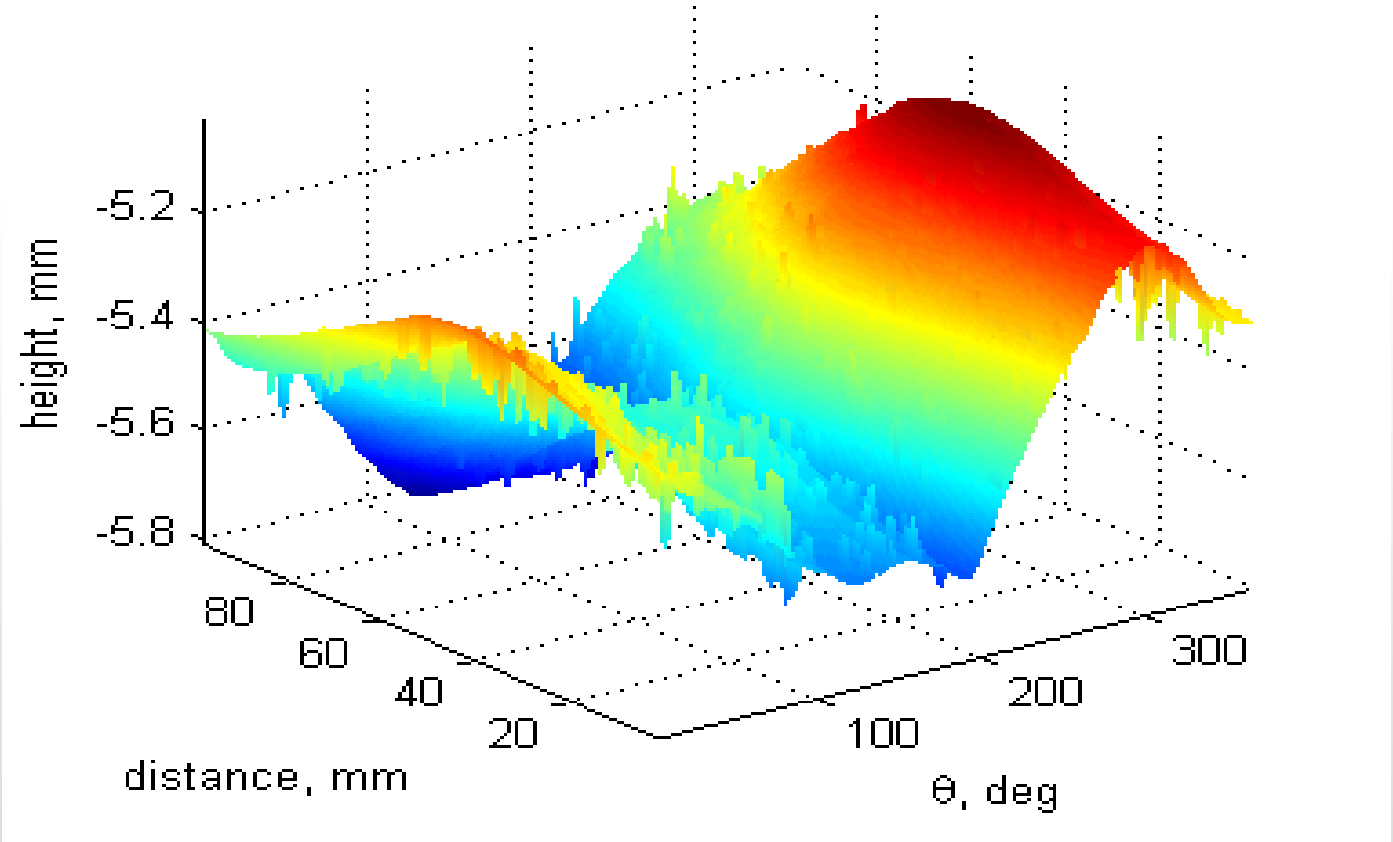
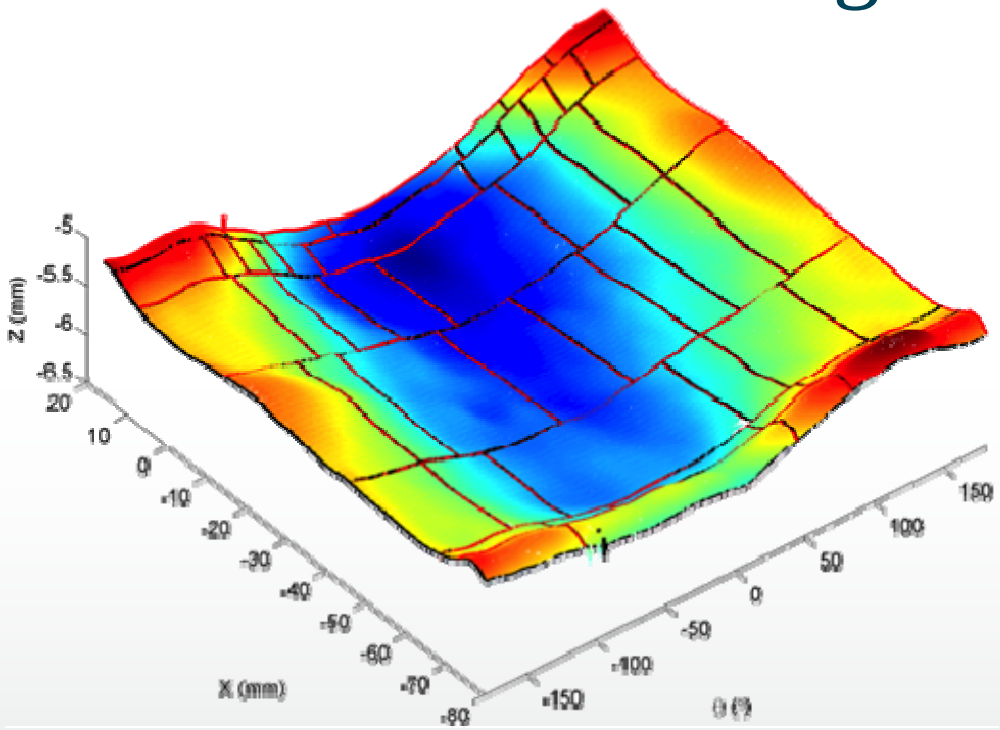
Measurement Issues – Range

- Artefacts are generally affected by non- concentricity that may exceed the sensor's gauge range

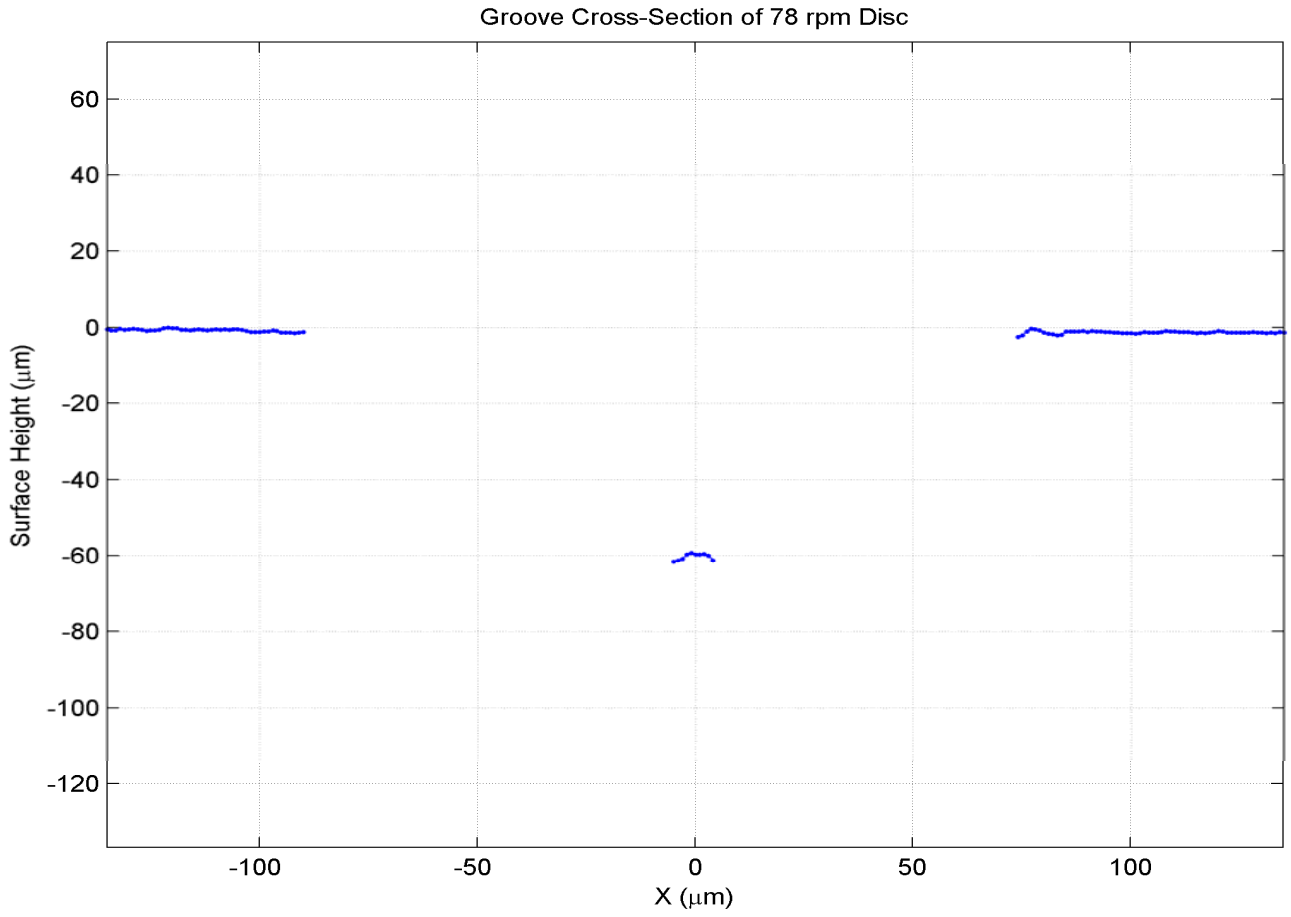


Measurement Issues – Range



- Limited sensor gauge range necessitates segmented surface
  - Surface is scanned at low resolution to estimate surface form
  - Optimisation program segments surface into manageable areas
  - Ideally surface should be scanned in complete annular rings

Measurement Issues – Angular Tolerance



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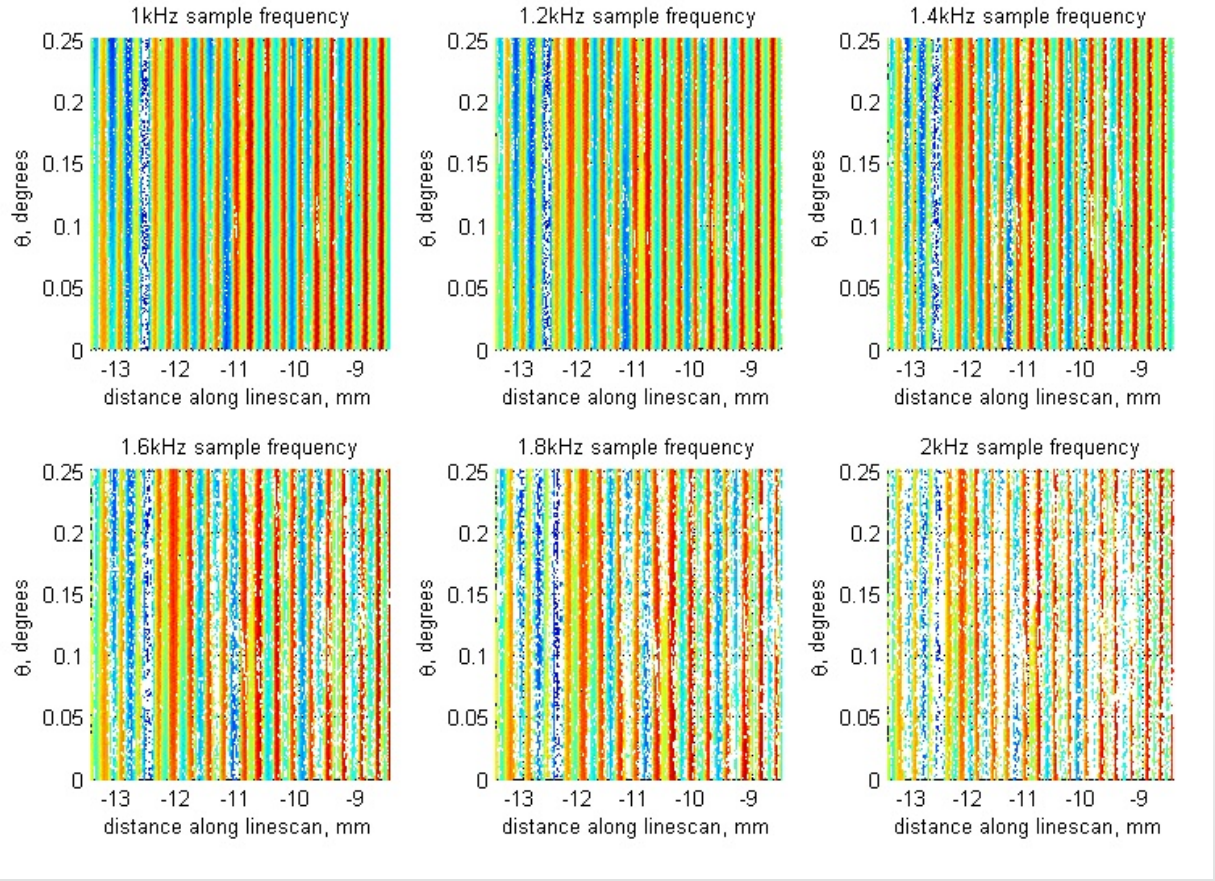
Measurement Issues – Speed

- Scanning for lowest resolution (9.6kHz) within 3-4 days
- Aim to scan cylinder in 24 hours for ACCESS
- Decreasing scan times limited by sensor sampling frequency



- Instead, need to multiplex sensor heads in an array

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Signal Extraction

- Stylus trajectory estimate based on phase shift estimation between linescans.
- Audio signal derived from estimate of groove depth, found along this stylus trajectory.
- Numerous signal estimates can be derived from a ‘Groove Matrix’.
- Minimum point of groove not suitable for depth estimate, due to variable groove cross-section.

Trajectory Estimate

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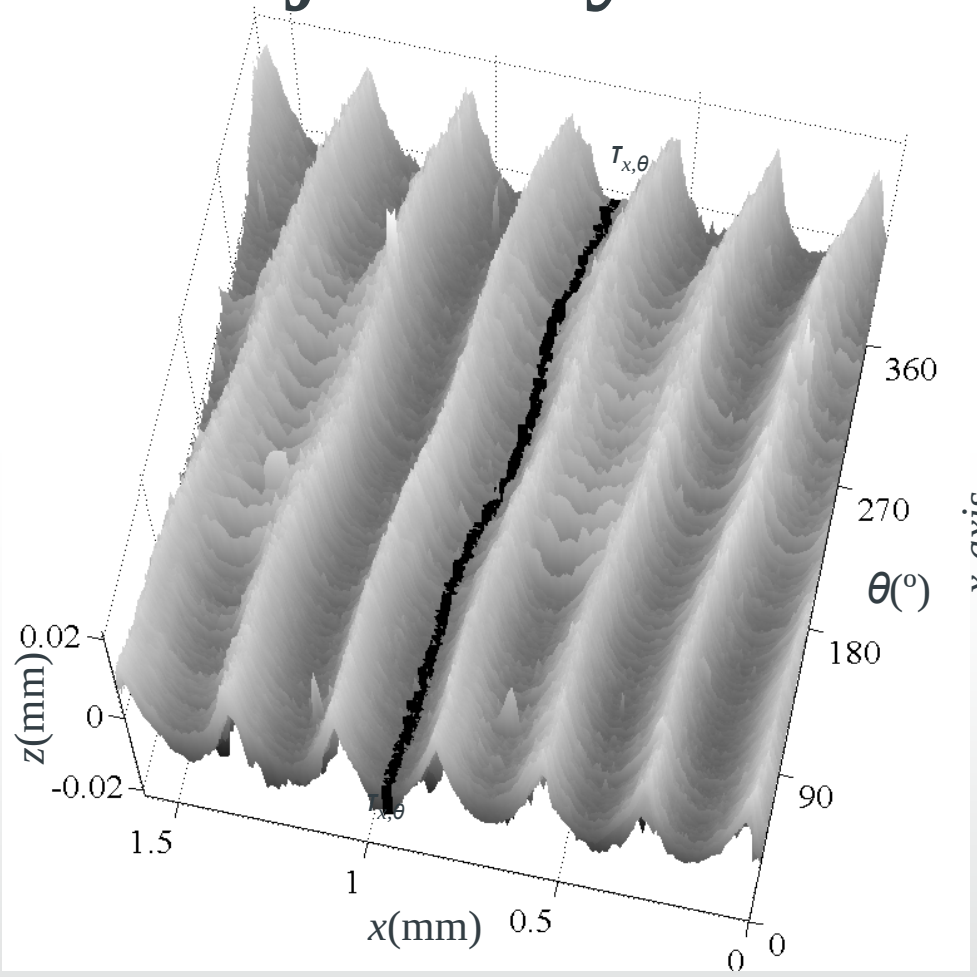

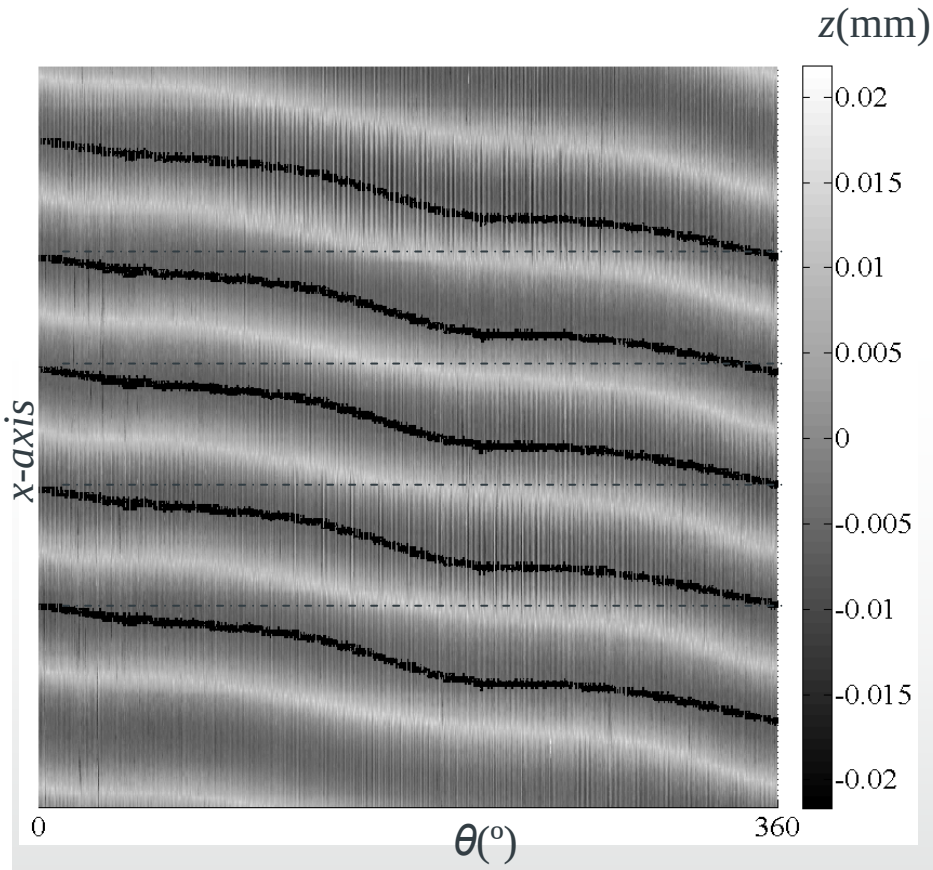

Trajectory estimate, $T_{x,\theta}$ is positioned along x-axis to form complete stylus trajectory.

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Groove Depth Estimate

- Need a discrete estimate for the groove depth for each groove cross-section at time *t*
- Groove bottom not always in the same place (asymmetric groove cross-section).
- Polynomial smoothing filter (Savitzky-Golay) used to locate the medial axis of the groove.

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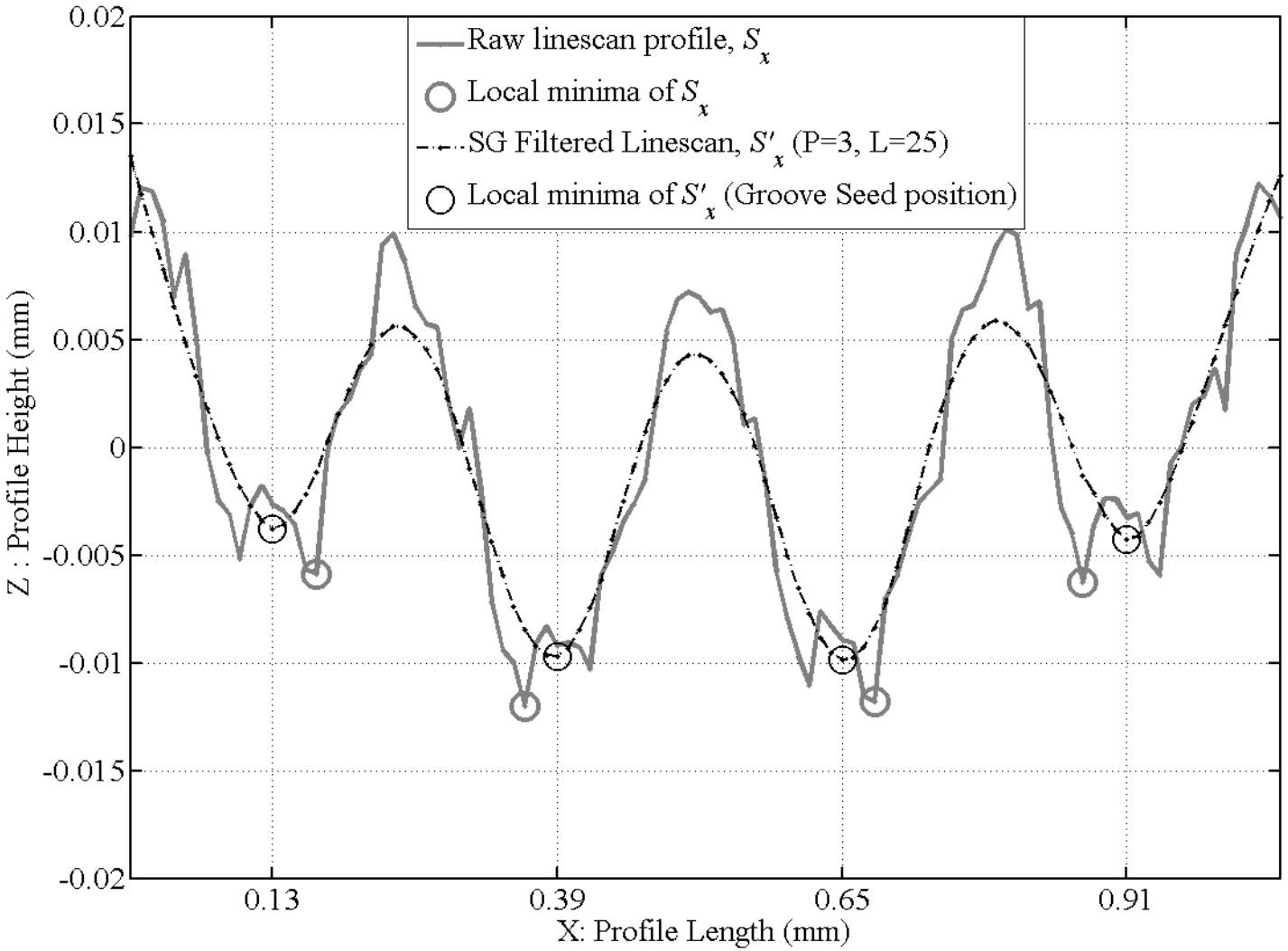
Groove Depth Estimate via SG Filter



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Case Studies

1. Miscellaneous Cylinders
2. Test Signal Cylinders
3. Evan Roberts Cylinder
4: Graphophone Cylinder (Queen Victoria)
5: Tinfoil Recording

Miscellaneous cylinders

- "Beautiful Birds Sing On", 1905 (9022: Edison Gold Moulded Record)
- "Lonesome", 1909 (1184: Indestructible Record) 
- "My Wild Irish Rose", 1910 (567: Edison Amberol)
- "The Preacher and the Bear", 1913 (1560: Edison Blue Amberol)
- “Just Before the Battle Mother”, 1912 (Edison Blue Amberol)

Available at : www.archivesound.co.uk

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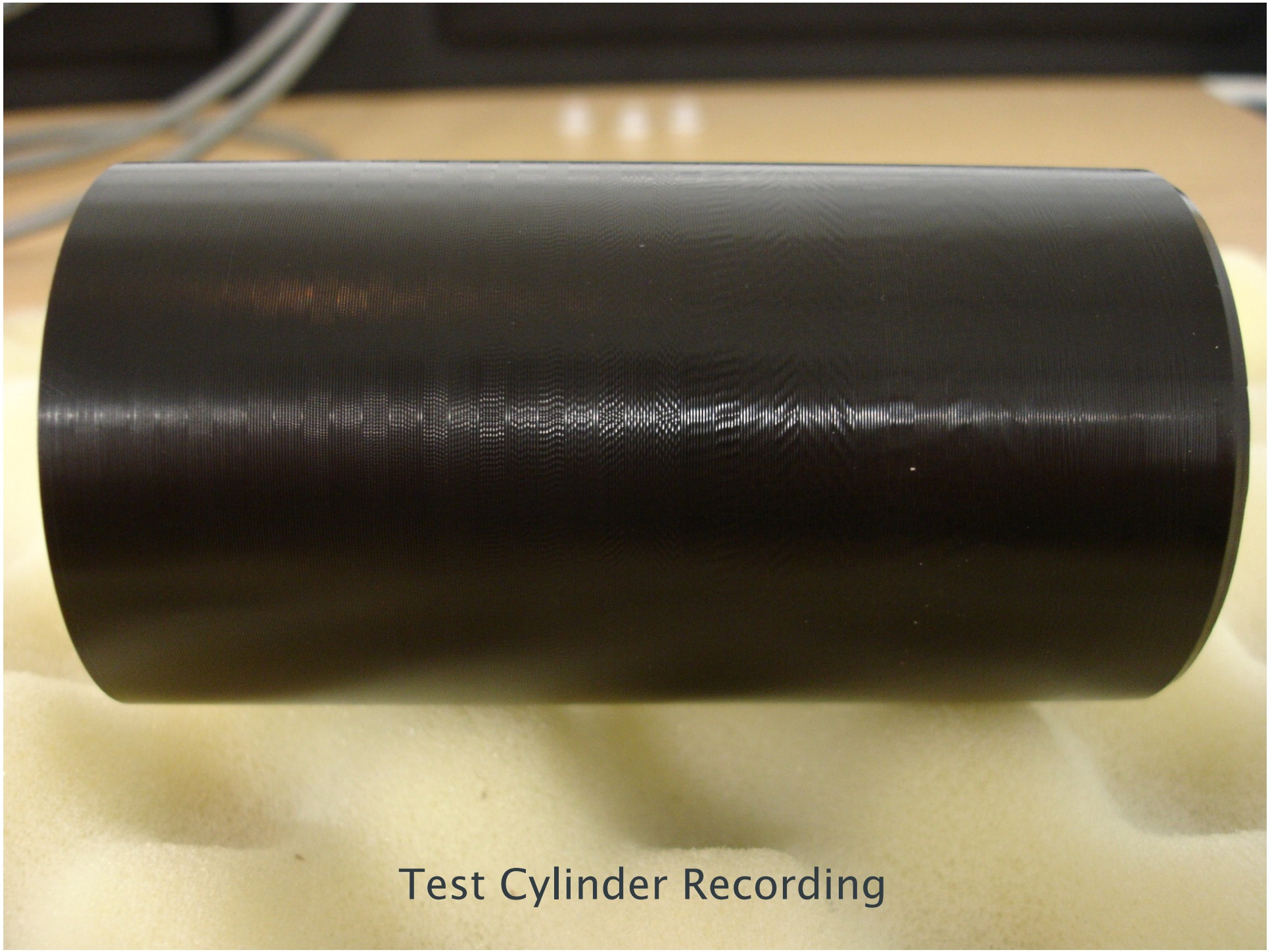
Case Study: Test Signal Cylinder

- Cylinder electrically recorded at Poppy Records for signal quality analysis.
- Sinusoidal tone bursts (50Hz – 5 kHz)
- 160rpm / 100 t.p.i
- Scanning Details :
  - Grid Sampling: $\Delta x = 10\ \mu\text{m}$, $\Delta\theta = 0.01°$
  - Playback sample rate: 96 kHz



Test Cylinder Recording

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Surface Details

- Monaural signal, stored in depth modulation.
- Surface in good condition (no cracks, low deformation)
- Groove cross-section is irregular, asymmetric (unlike typical Amberol cylinder).

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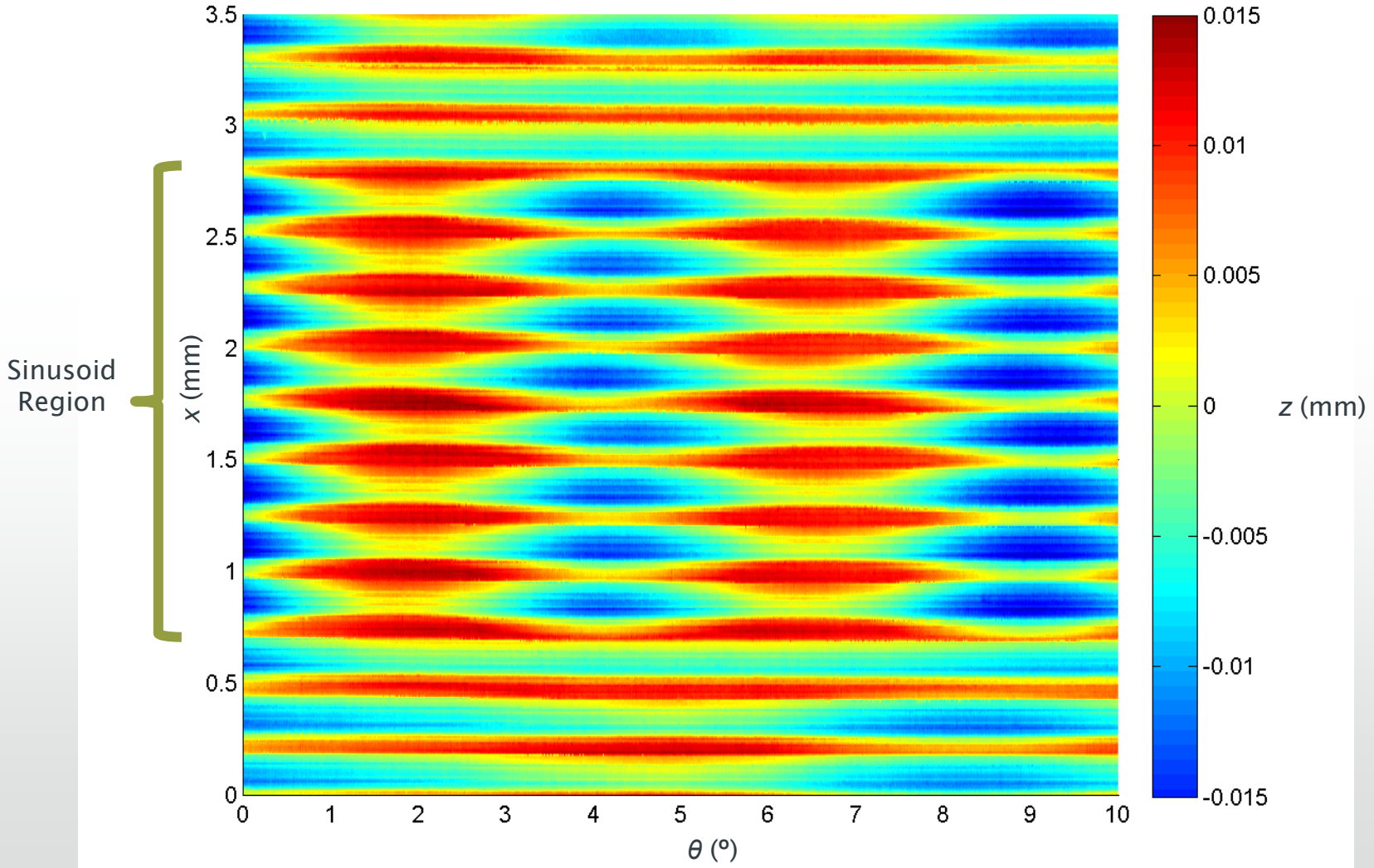
Test Cylinder Surface



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Test Signals

- Signals can be evaluated in terms of Signal-to-Noise Ratio (SNR) and Total Harmonic Distortion (THD).
- Comparisons with Stylus reproduction.
- Stylus transfer carried out by Will Prentice at BL.

Example Audio

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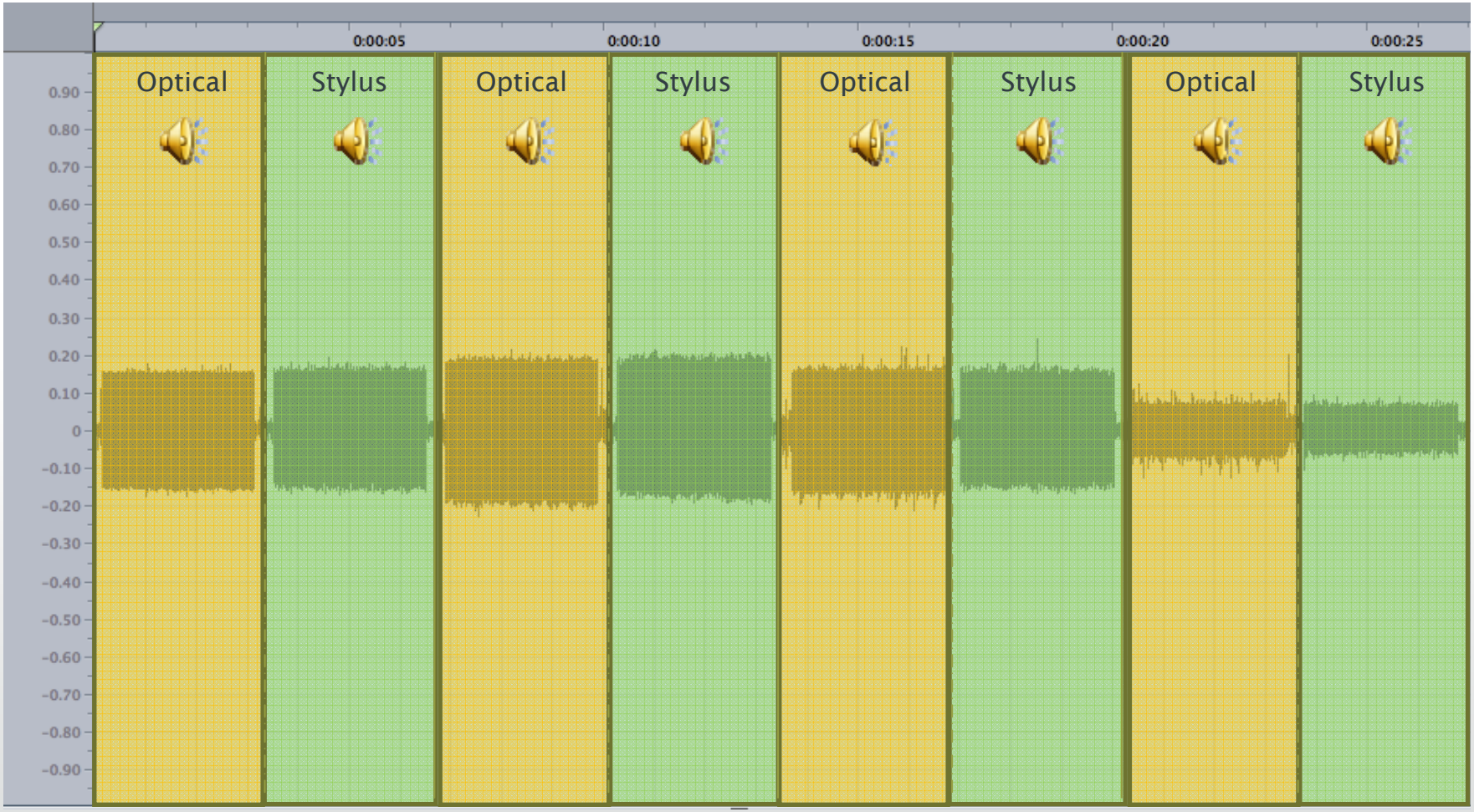
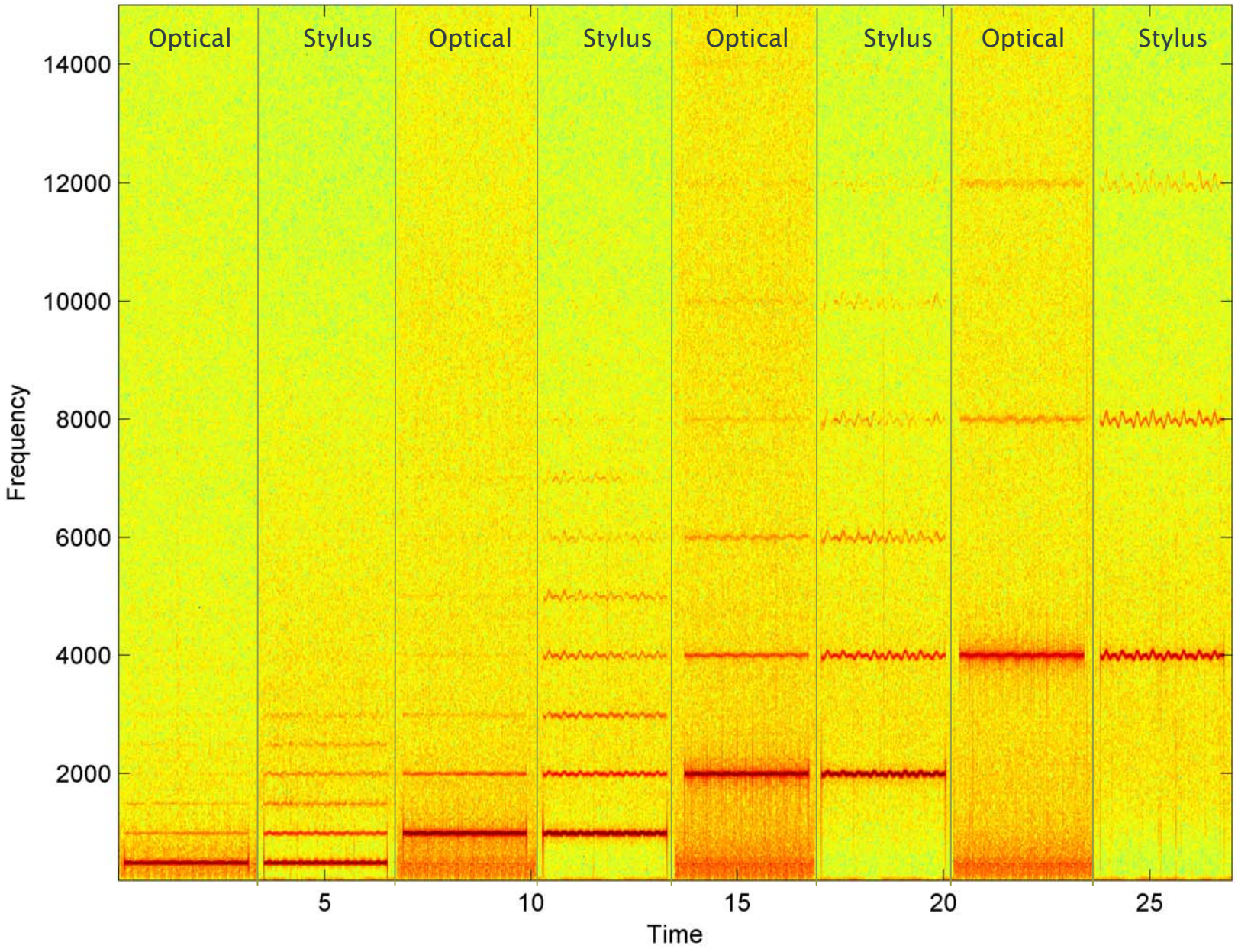


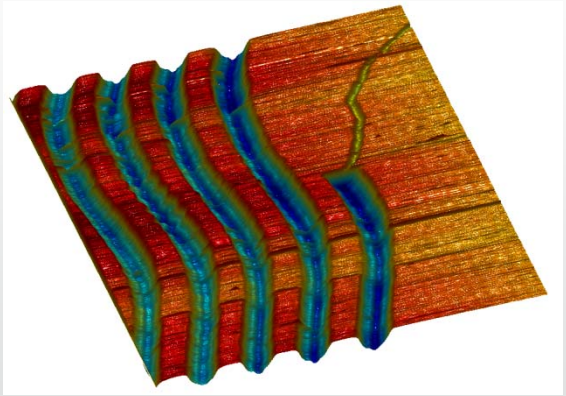
500 Hz 1 kHz 2 kHz 4 kHz

Time-frequency analysis to show frequency modulation and harmonic distortion

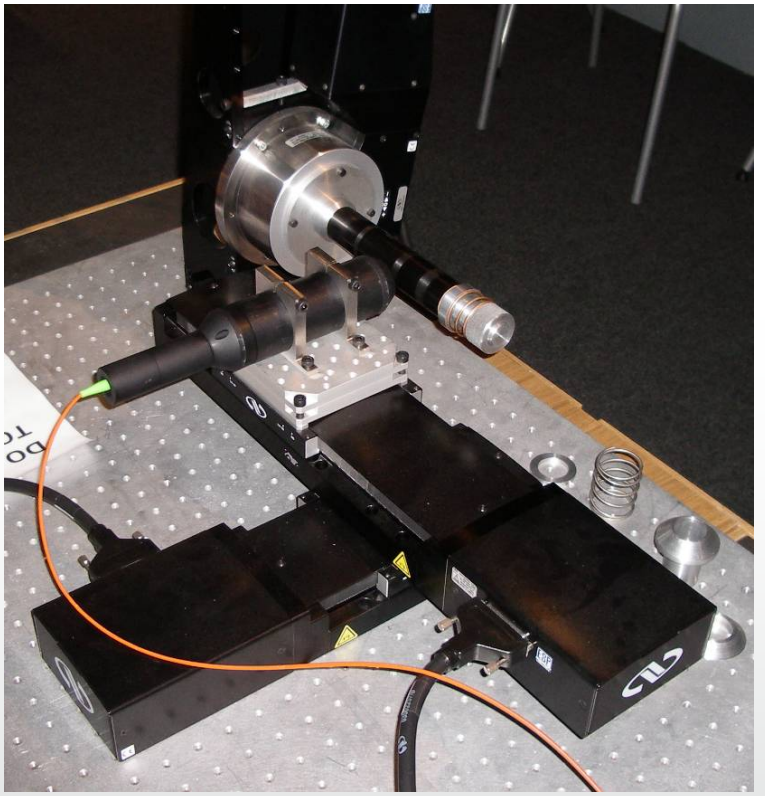


Case Study: “The Queen Victoria” cylinder

- Cylinder initially scanned in 2005
- Sound recovery from data unsatisfactory
- Consistent wear feature observed at bottom of the groove, thought to be modern stylus damage



Data from end of Victoria track



Graphophone cylinder mounted on system at Science Museum

Study: Identifying Wear from Stylus Playback

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- Artefact: Brown Wax Cylinder c.1888.
- Reported to contain the voice of Queen Victoria.

Identifying Wear

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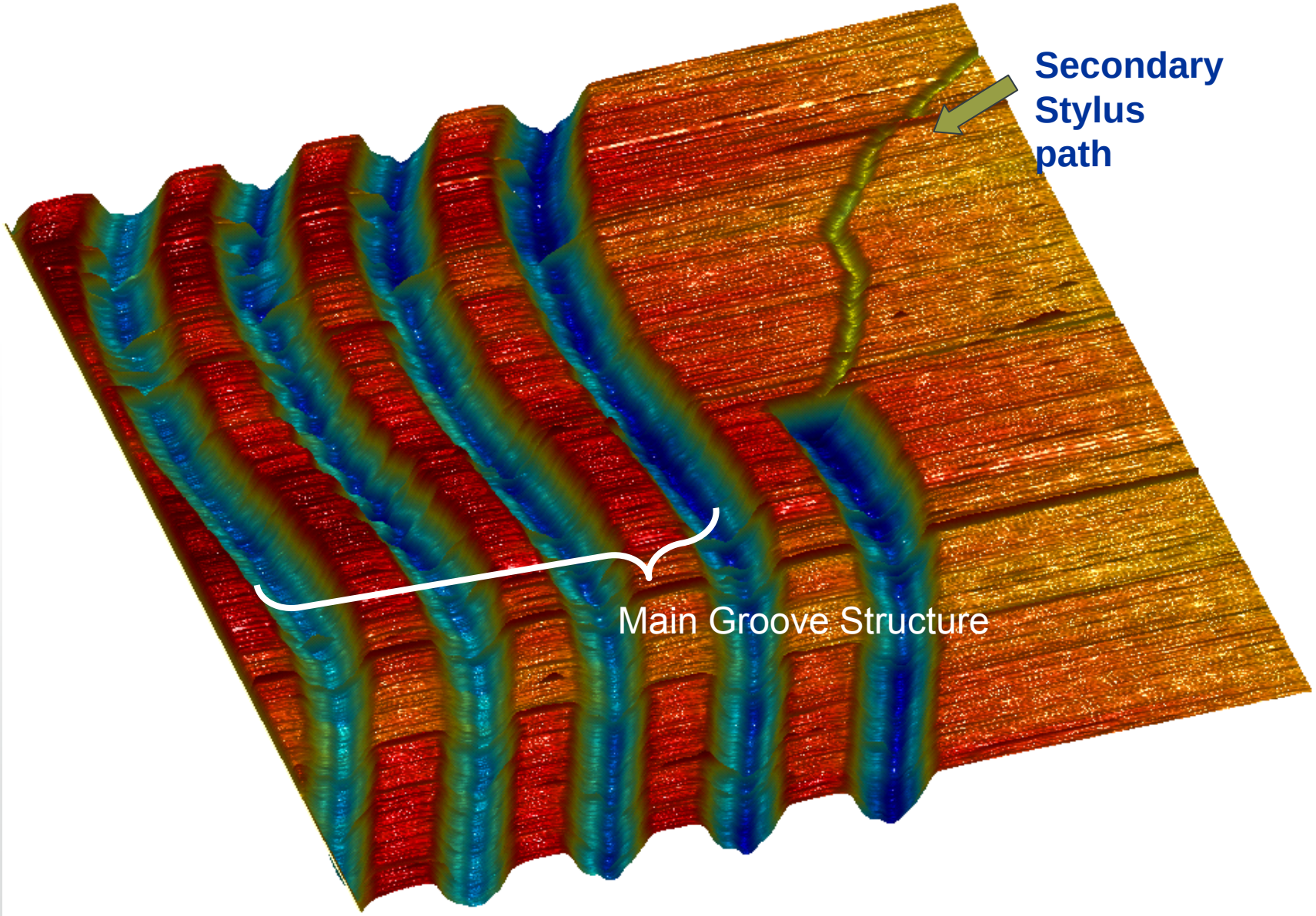

Identifying Wear

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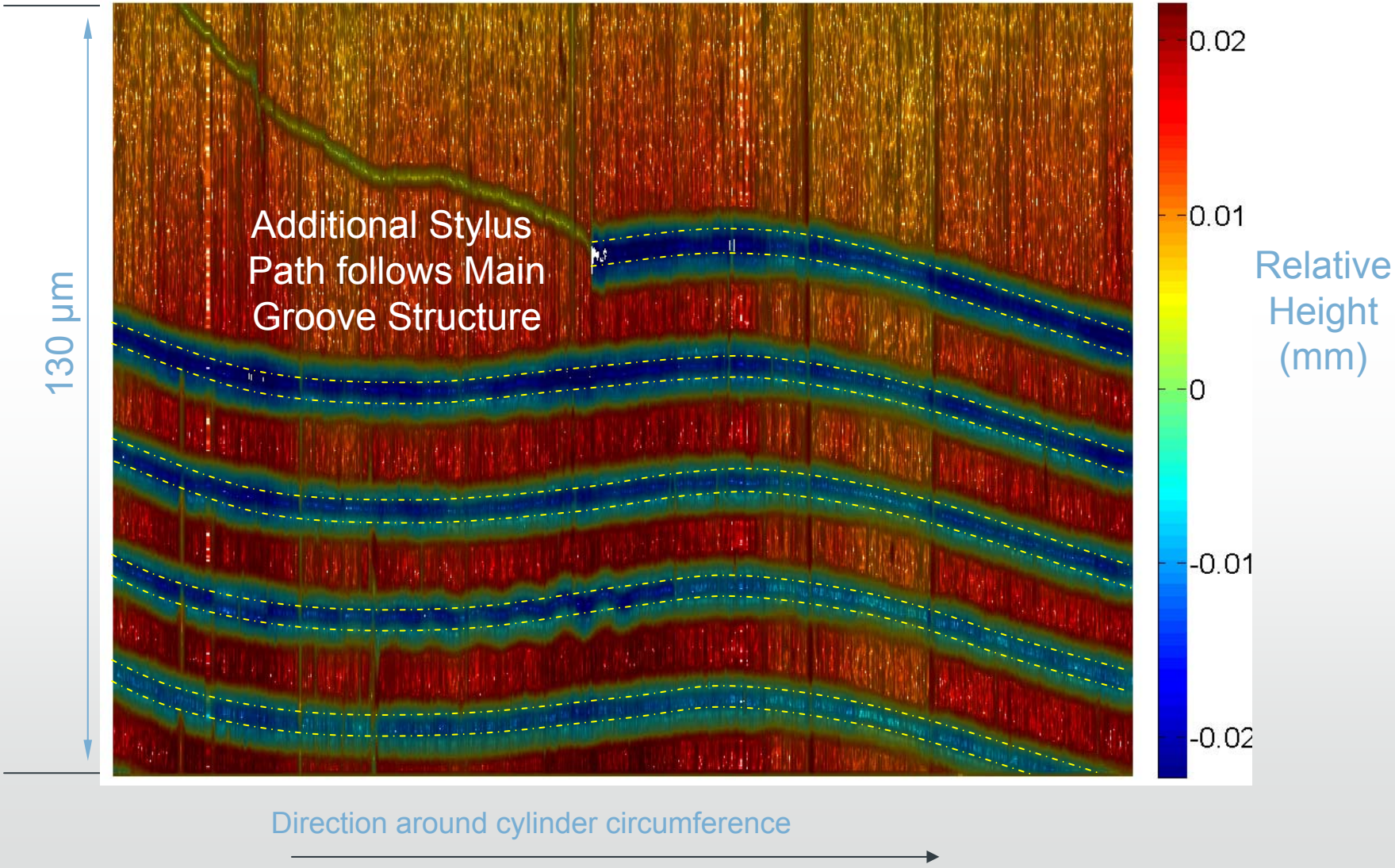

Groove Shape Profile

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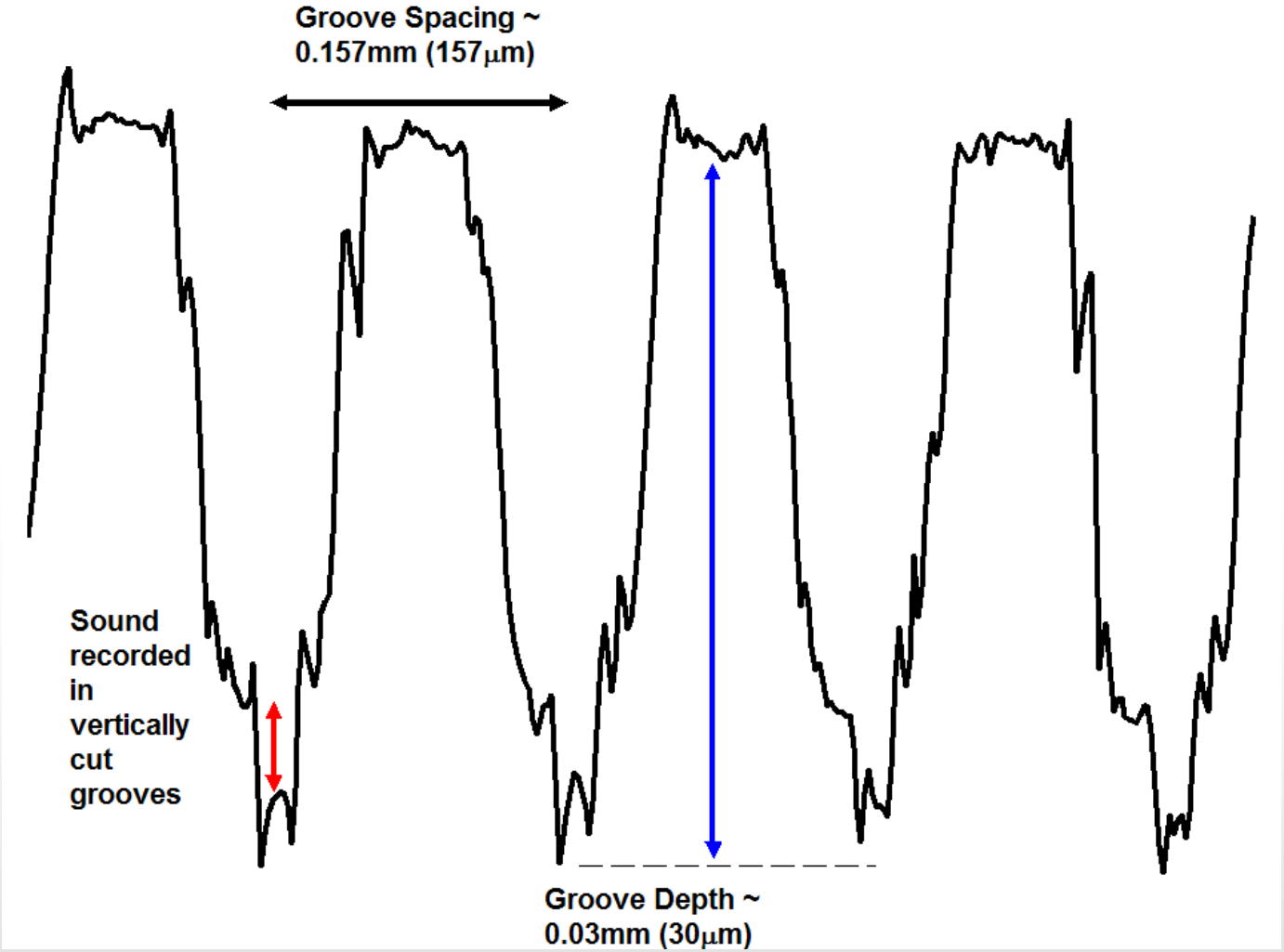
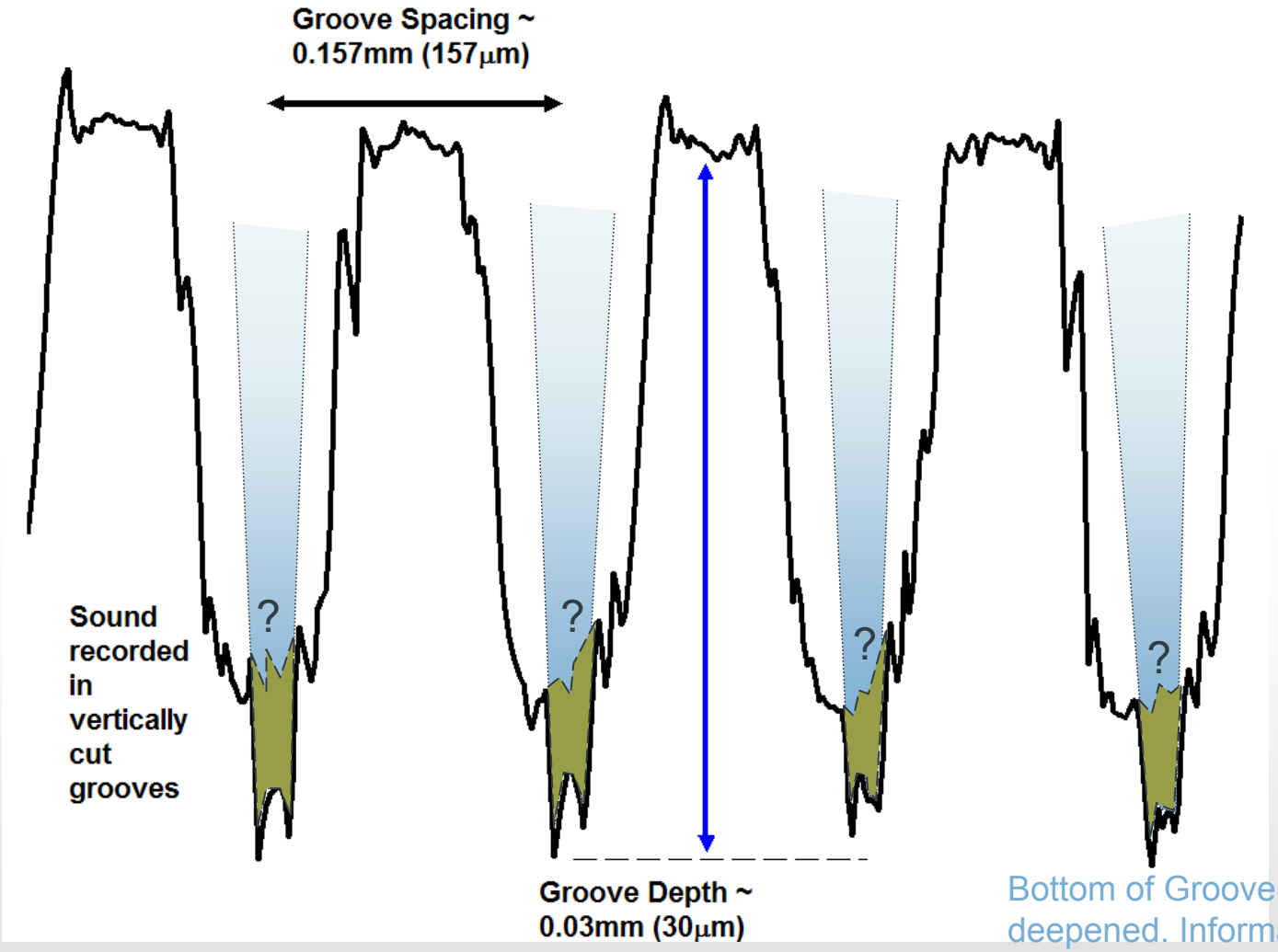


Effect of Additional Stylus



Bottom of Groove Has been deepened. Information lost.

Other Examples of Wear

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Main Groove Structure

Solution?

- Recovering sound from *inside* 'wear region' proved unsatisfactory.
- The 'Virtual Stylus' can be placed anywhere in the groove.
- Observe groove features and recover sound *outside* of the 'wear region'.

Groove Features

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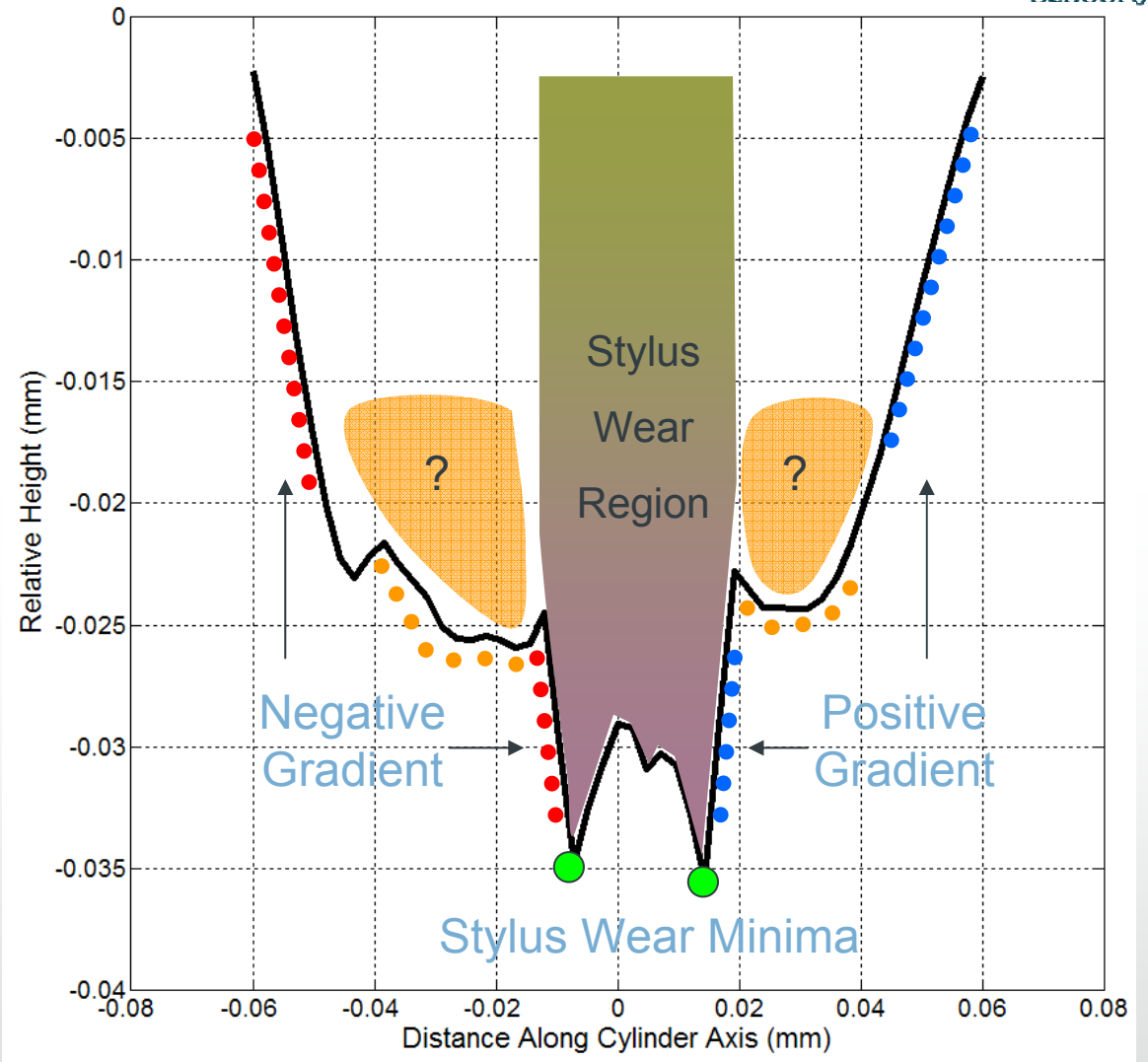

Feature Map

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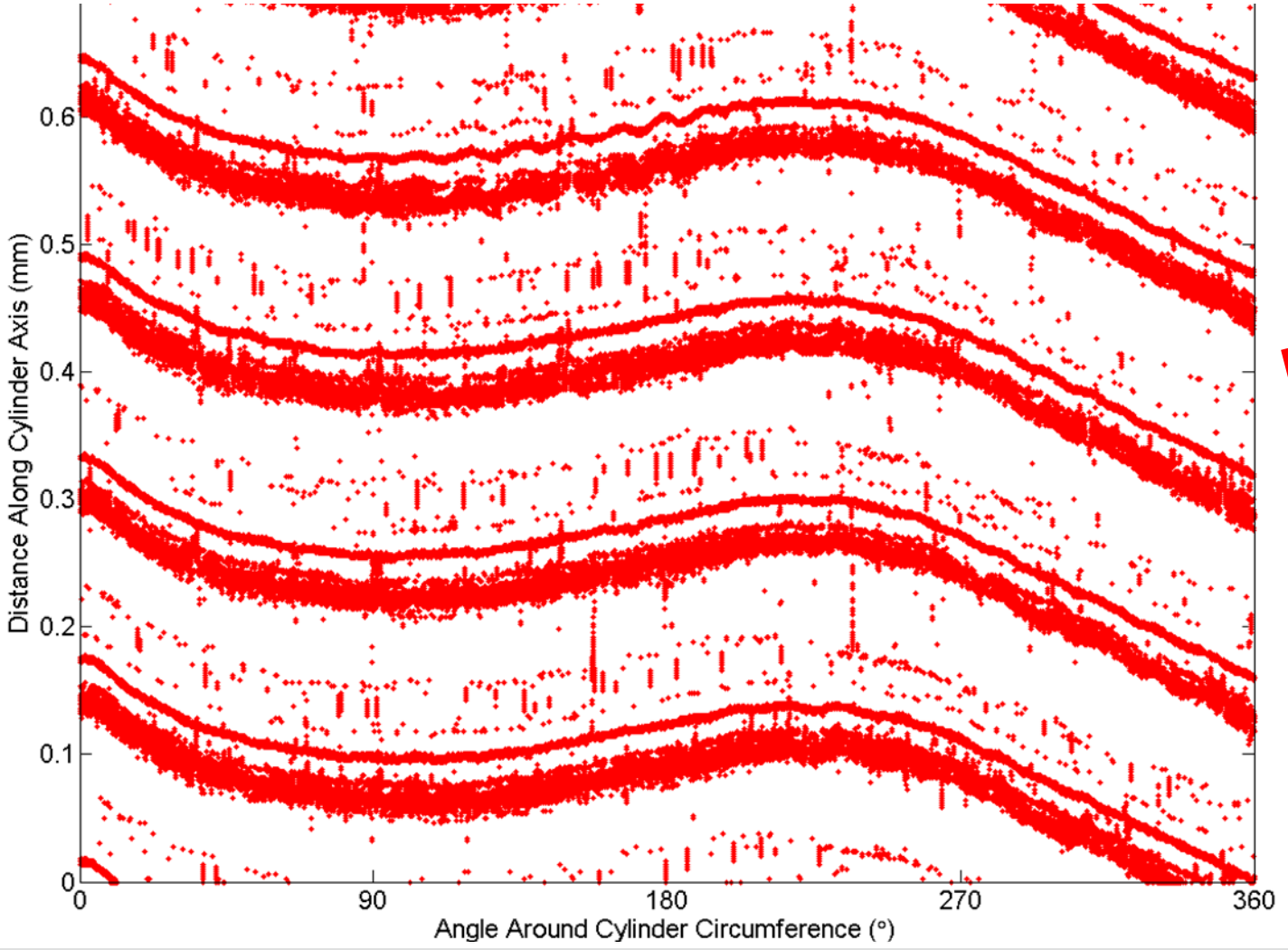

Groove Shape

Feature Map

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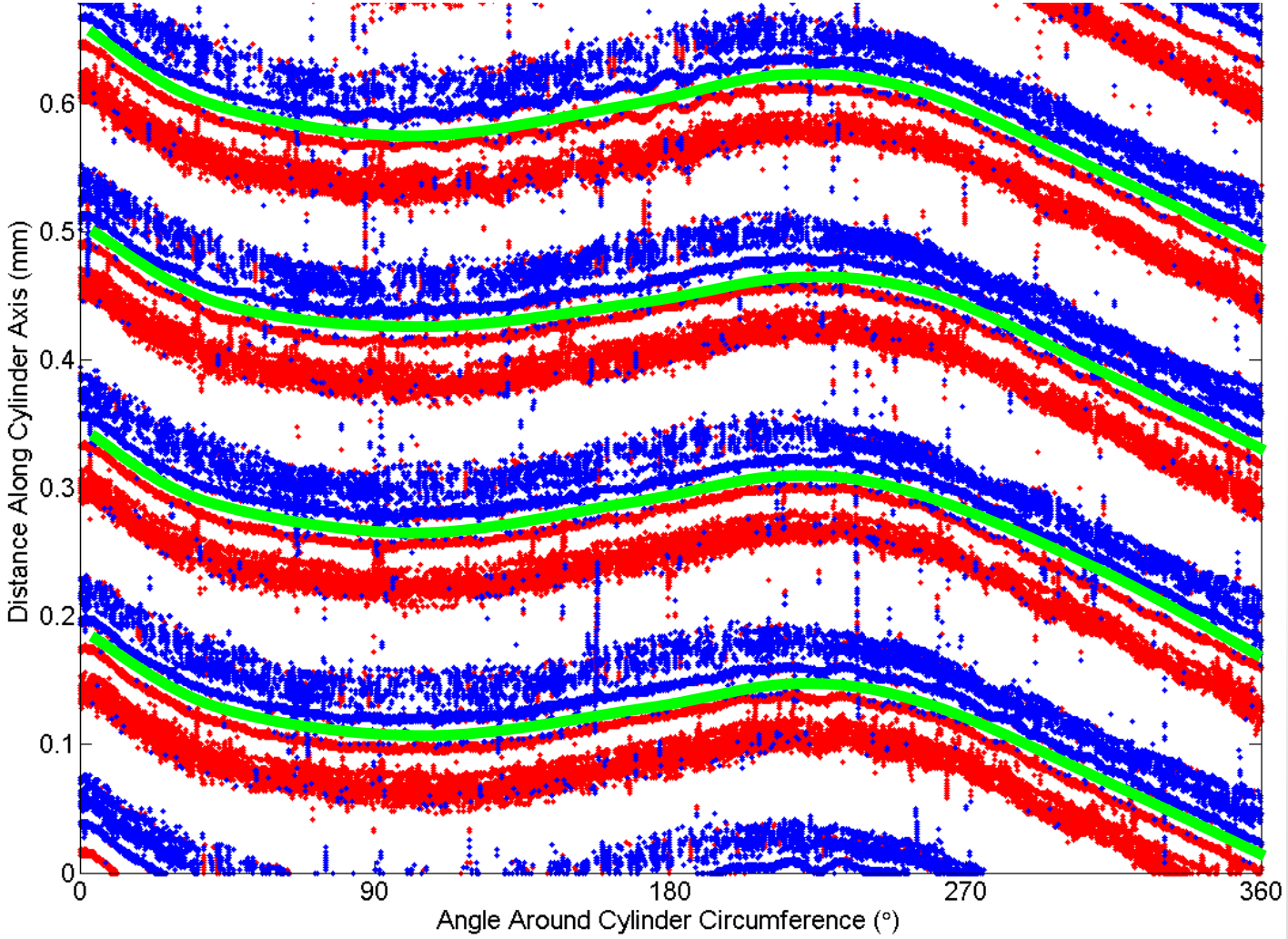
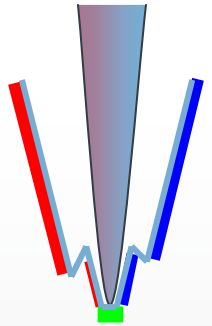
Negative Gradient



Groove Shape



'Virtual' Stylus

Her Majesty spoke a few words?...

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- Words not intelligible, but definite periods of speech are audible.

Audio extracted *inside* 'wear' region

Initial Audio extracted *outside* of 'wear' region

N.B. Both files identically band-pass filtered 400-1800Hz

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Advanced Studies

- A. Rule based searching for the sound carrying features.
  - Averaging data over region.
  - Vertical slice level
  - Limits on the X position
  - No use of bad data
- B. Feature tracking, addition. This has no added improvement.
- C. Adaptive Filtering of the Displacement track.

Advanced Studies: A&B

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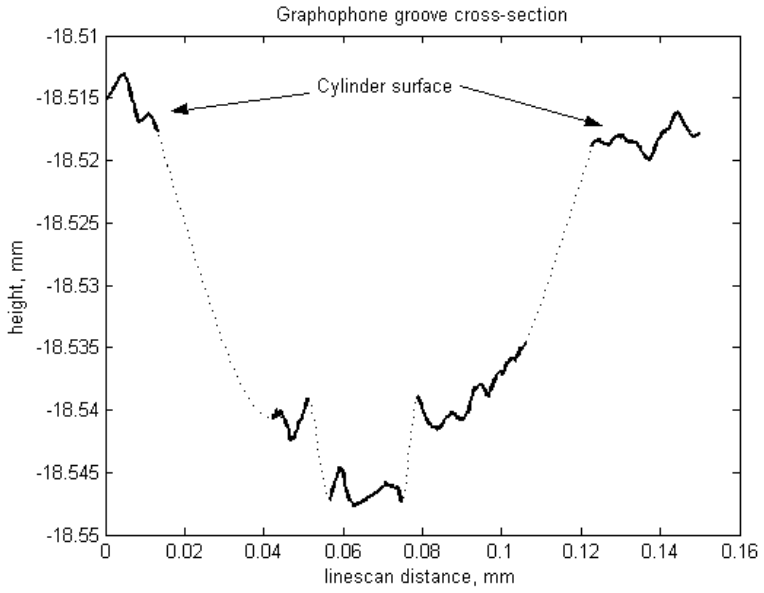
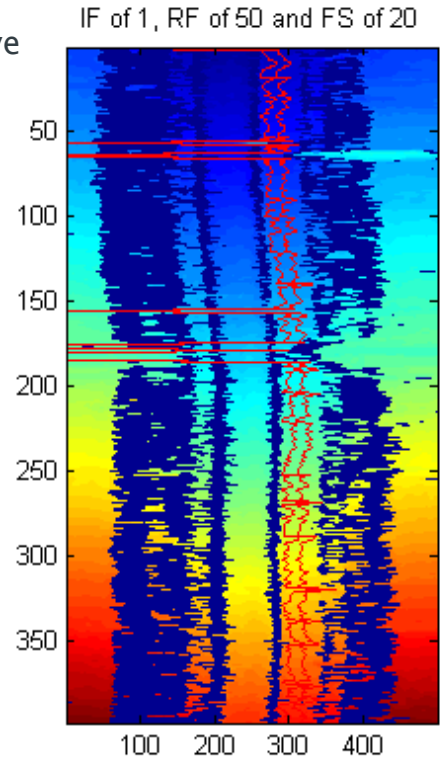
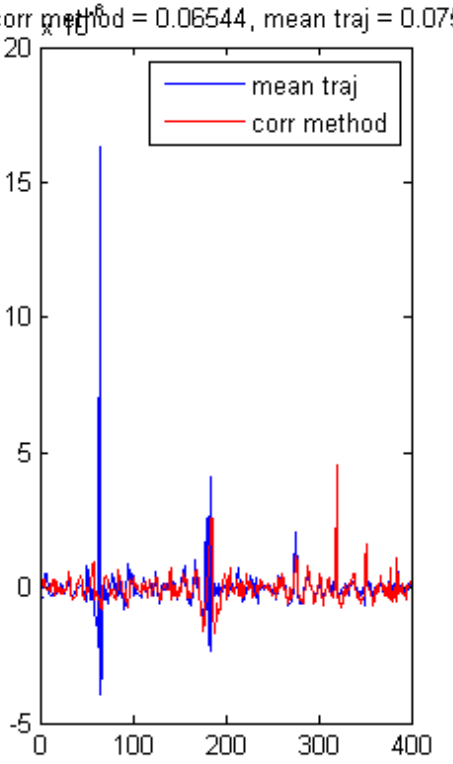
Feature tracking used to extract audio from right hand plateau region of groove







Typical Victoria graphophone groove cross-section. Regions of data loss are interpolated using the dotted line for presentation clarity

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Greetings ****** the answer *can be * (Lord Granville?) (absolutely?) has never forgotten

Lord Granville was Foreign Secretary 28 April 1880 – 24 June 1885.

Original Stylus Transfer, with filtering.

Feature Tracking, with band pass 400-1800Hz.

Filtered by the BL using commercial software

THE ROYAL ARCHIVES

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20 April, 2007

Dear Professor McBride,

Thank you for your letter of 22 March concerning your research on the Science Museum recording of Queen Victoria's voice.

Lady Longford, who wrote a biography of the Queen in the 1960s, had mentioned this recording, and in the 1990s thought, wrongly, that her source had been the Queen's Journal. Since Paul Tritton's book was published, we have discovered that her source was a letter from the Queen's Private Secretary, Sir Henry Ponsonby, to his wife, Mary, which has come into the Royal Archives since 1991. The letter, dated 29 August 1888, states 'A man friend of Miss Bauer [Paul Tritton's book explains this link] came here yesterday with a graphophone. It is different from Edison's phonograph and has been made by Bell (who we once saw with Johnny), his brother and some others and is very ingenious – no electric or magnetic currents – simply worked like a sewing machine with a treadle. Little cylinders revolve which a little machinery marks with your voice – and the contrary returns your voice through a pipe into your ear. Only one can really hear it, but it is very curious. Wernher [a member of the Household of the Grand Duke of Hesse, one of Queen Victoria's sons-in-law, who was visiting her at the time] spoke in German, Edwards [Major Fleetwood Edwards, a Groom in Waiting] whistled and I laughed – my 'coachman's laugh' – it was most extraordinary the clear way this was reproduced – as often as one liked. The Queen said to me at dinner 'I heard your hearty laugh this evening'. This was 6 hours afterwards & he says it will keep for years. HM spoke into it – but we told Mr Morse he must not go round the country reproducing the Queen's words.'

Advanced Studies: C

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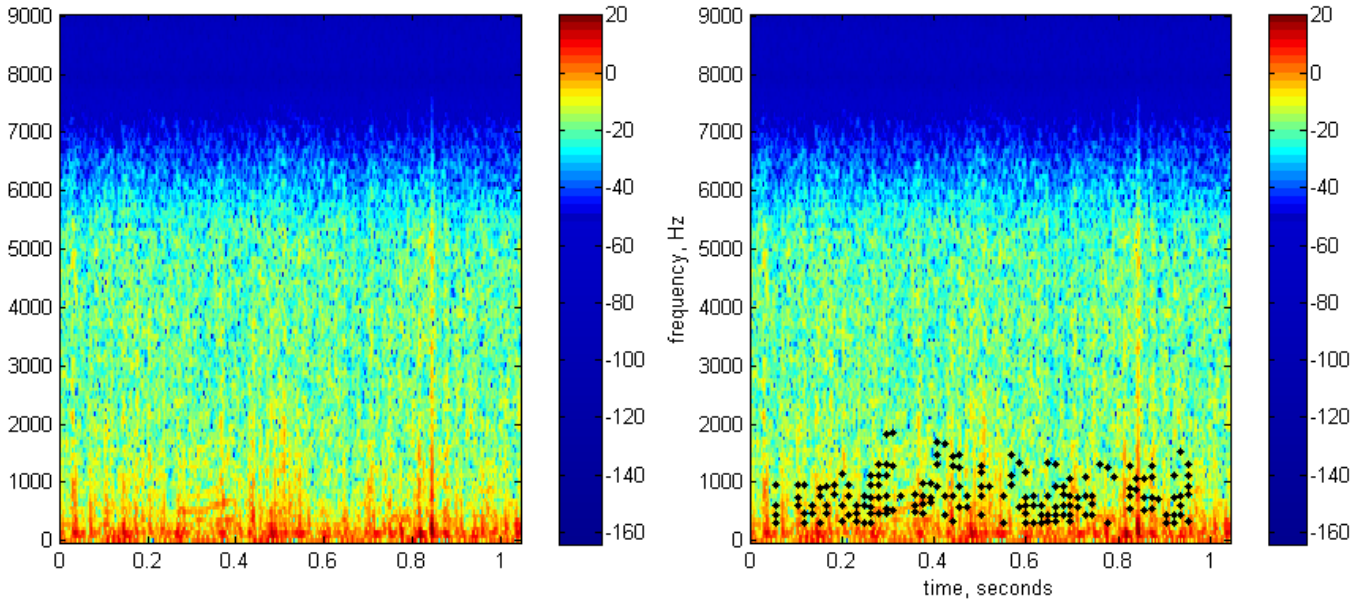

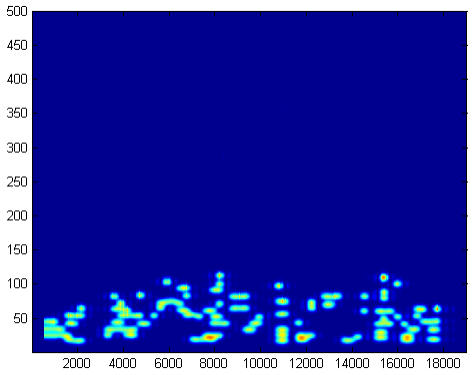

Probable vocal components, and the adaptive filter used for equalisation

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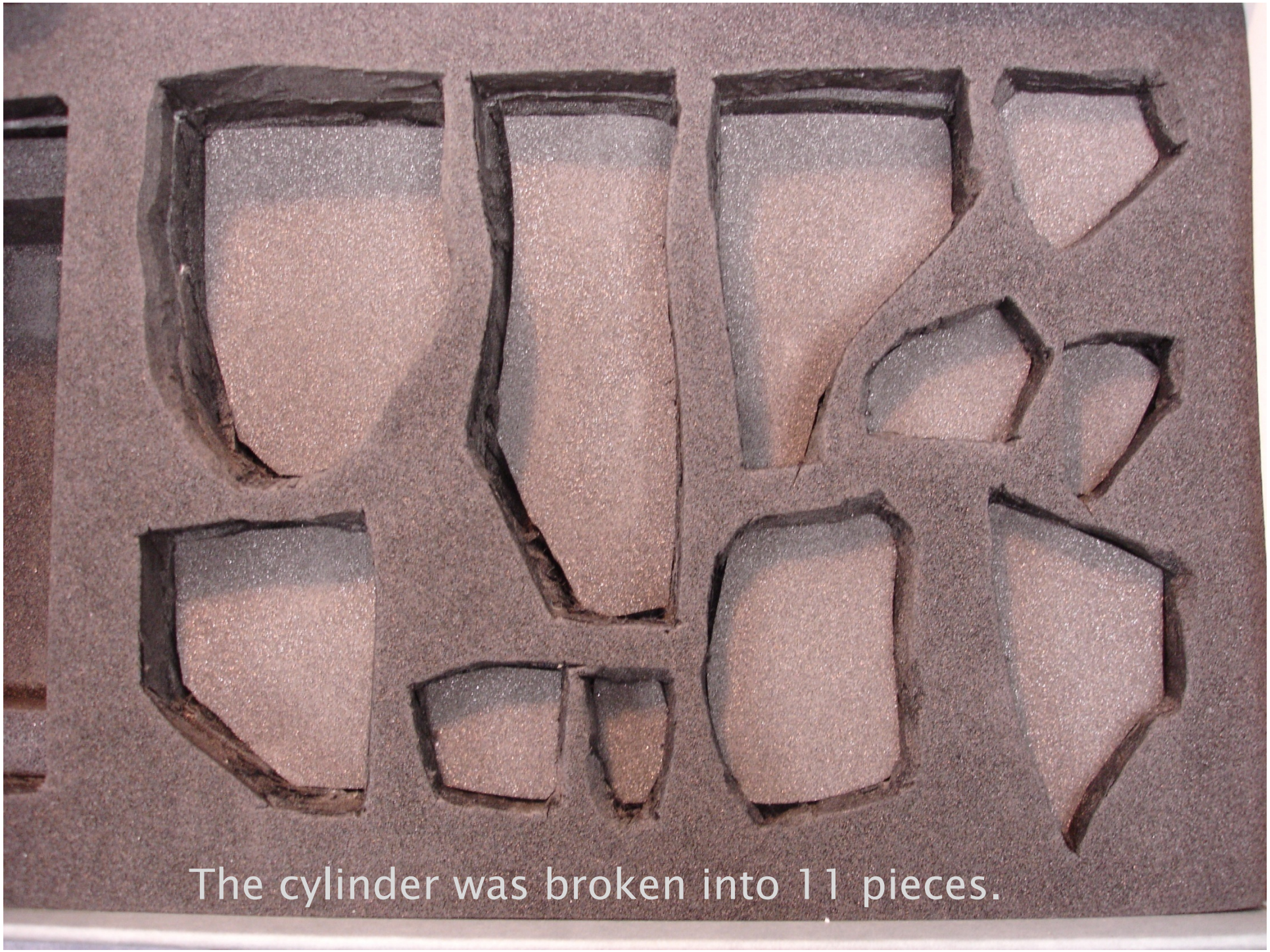
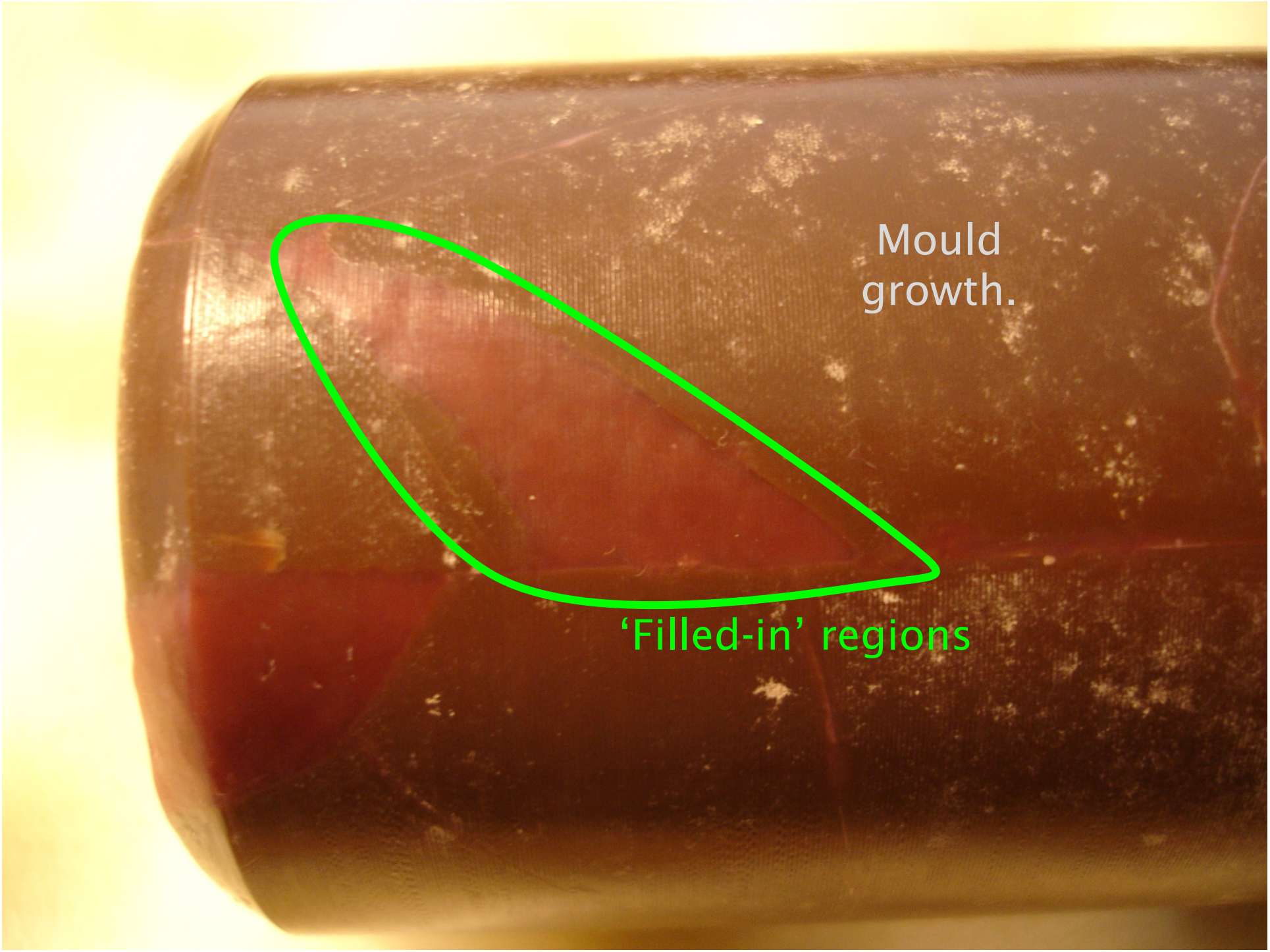
Case Study: Evan Roberts Cylinder

- Wax cylinder of Welsh Preacher c.1905
- Contains spoken word and chorus.
- Cylinder was broken and repaired.
- Stylus Transfer made prior to scan.
- Scanning Details
  - Grid Sampling: $\Delta x = 10\ \mu\text{m}$, $\Delta\theta = 0.02°$
  - Playback Sample rate: 48 kHz

www.bbc.co.uk/wales/southwest/halloffame/public_life/evanroberts.shtml


The cylinder was broken into 11 pieces.

Reconstructed cylinder.


Mould
growth.
‘Filled-in’ regions

Evan Roberts Cylinder Surface

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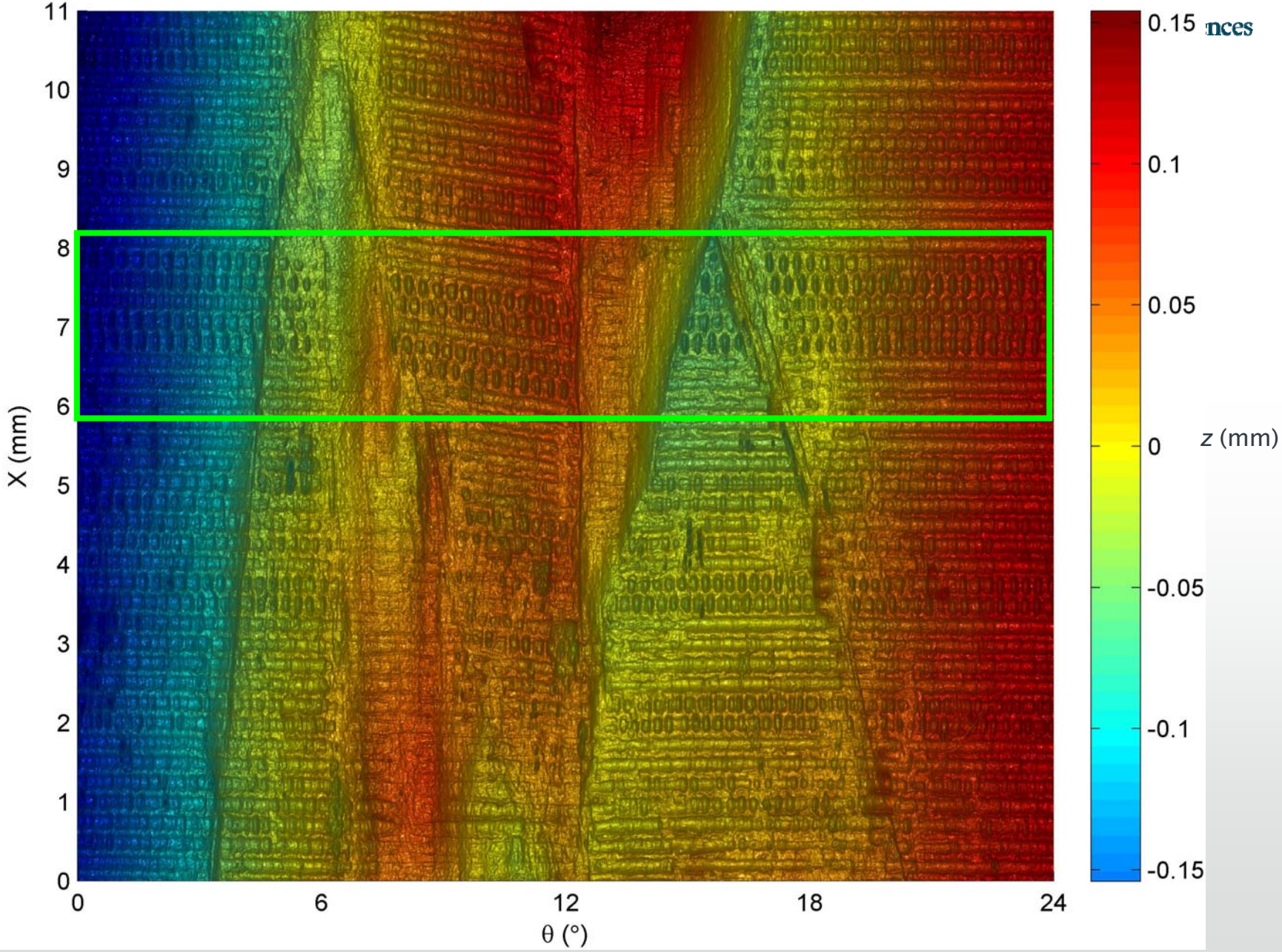

Trajectory Estimation

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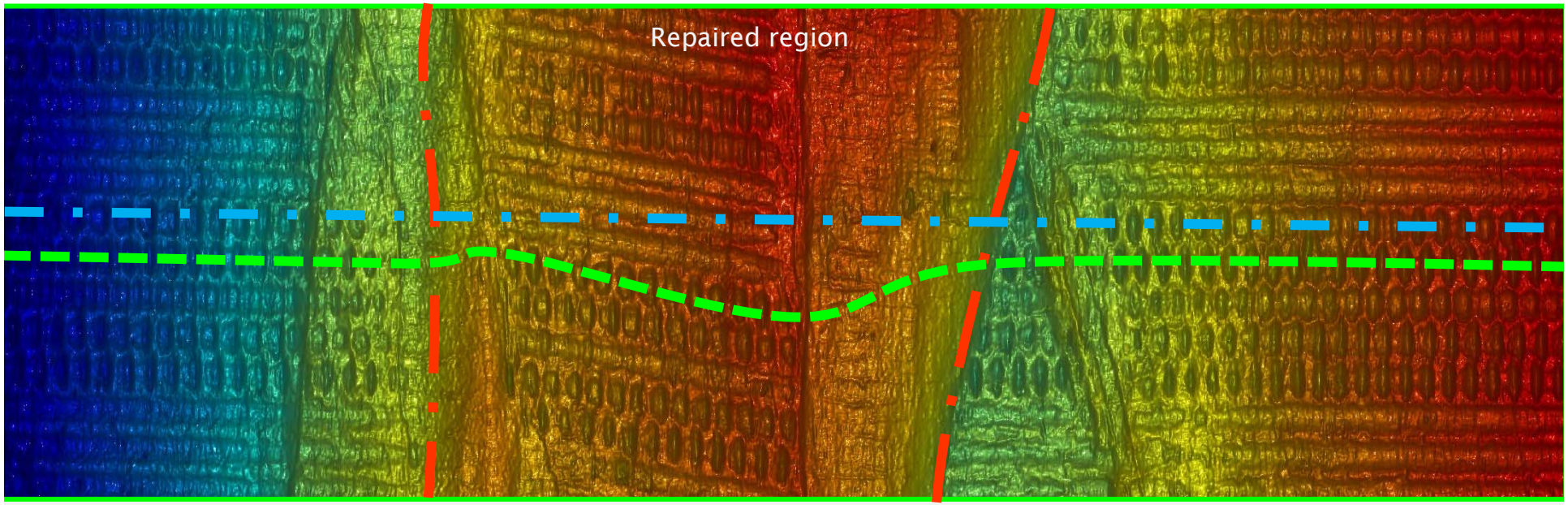
- Close examination of the surface allows for correct tracking of the grooves.



Ideal Stylus Trajectory (traced by leadscrew)

Actual Stylus Trajectory due to surface reconstruction

- Local trajectory estimation based on tracking of groove minima, using ‘Minima Map’.

Example Audio

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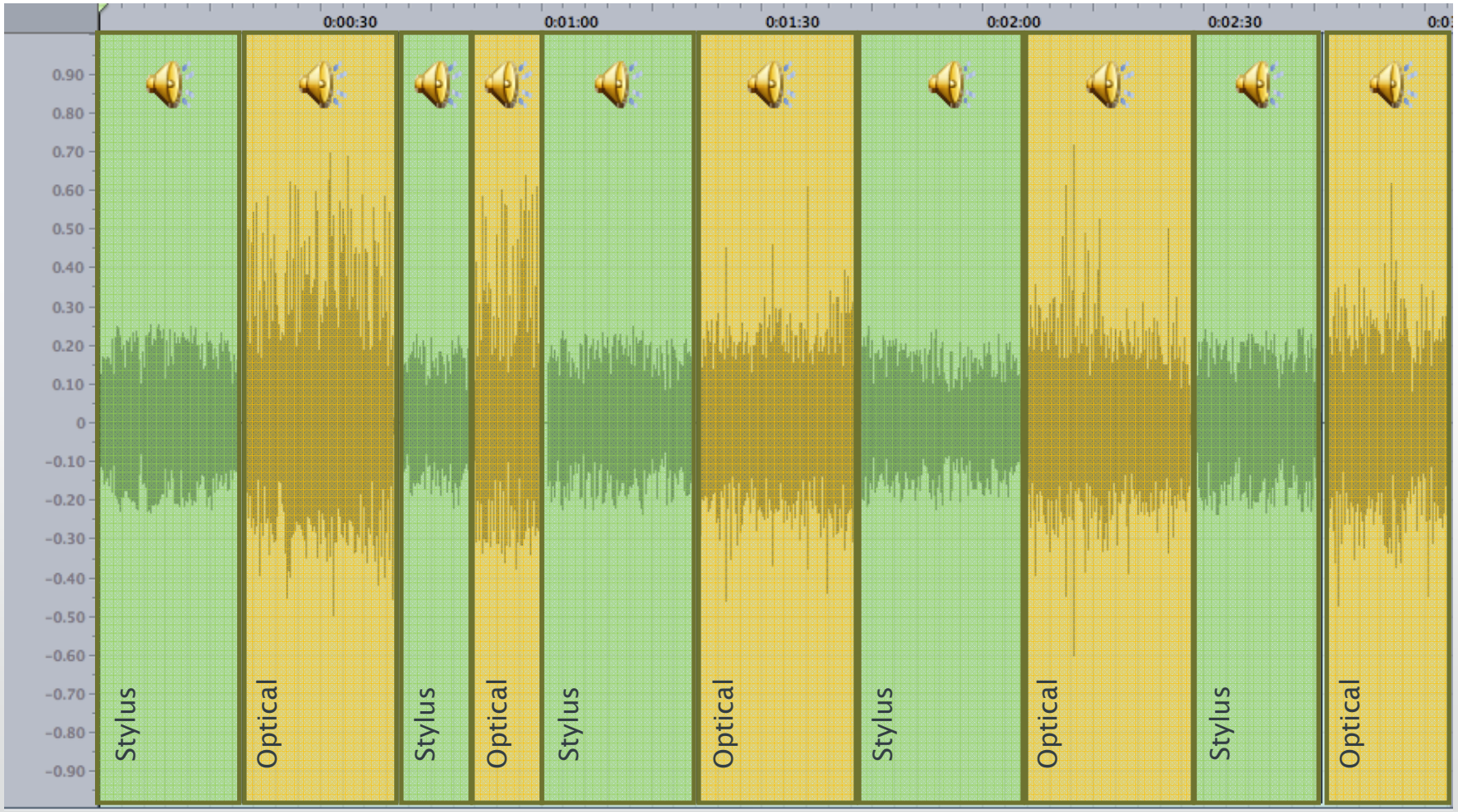
- Stylus transfer made in Los Angeles and further work carried out at the British Library Sound Archive.
- No noise reduction applied to optical transfer.



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Case Study: Tinfoil Recording

- British Library's earliest sound recording
- Edison tinfoil c.1877
- Badly folded and ripped
- Podcast on the British library Web site, follow the link from:
- http://www.sesnet.soton.ac.uk/archivesound/media/

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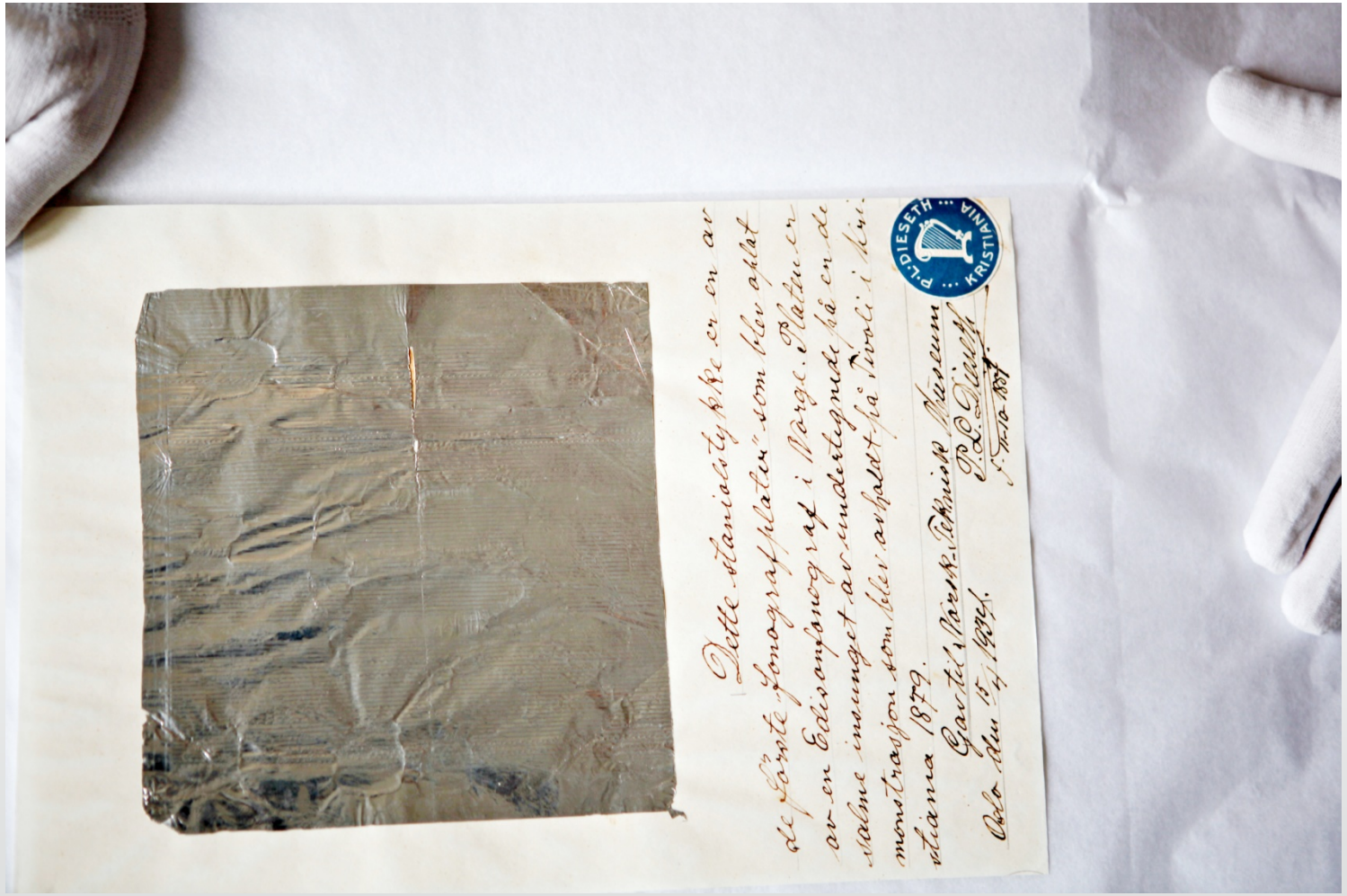
Norwegian Museum of Science &Technology



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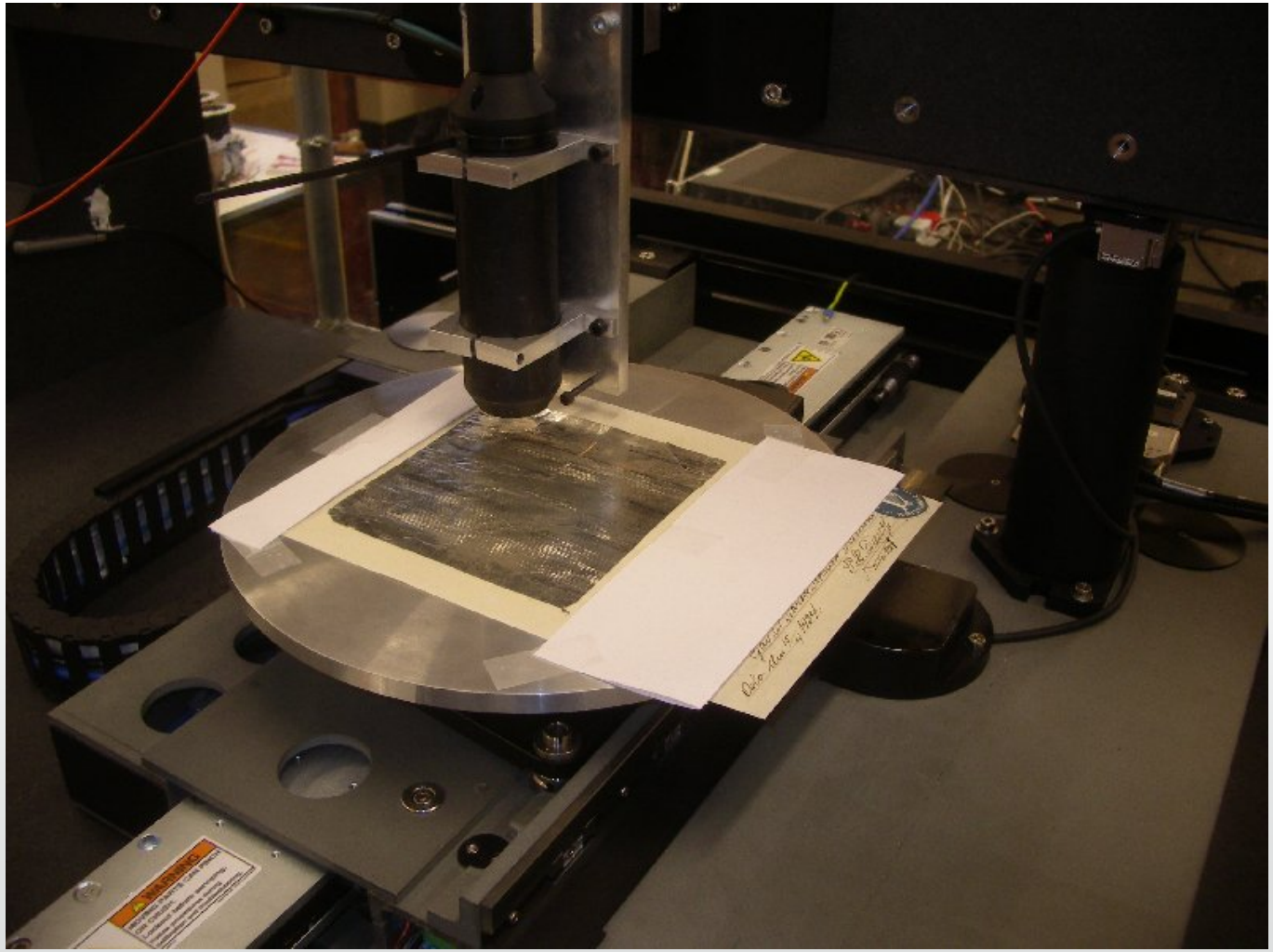

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Case Study: BL Tinfoil Recording

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Case Study: 78rpm Disk

- *"Make it a Party Pt. 1 / Pt.2"*, (1956)
- Artist: Winifred Atwell
- Decca F10796
- Playback Speed : 78rpm

- Scanning Details:
  - Grid Sampling: $\Delta x = 1\ \mu\text{m}$, $\Delta\theta = 0.05°$
  - Playback Sample rate: 9.6 kHz

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Surface Details

- Monaural signal in lateral, not vertical modulation.
- Data missing data at side walls, due to sensor's angular tolerance.
- Groove bottom not as well defined as the interface between the land and groove walls.

Groove Wall Edge Detection

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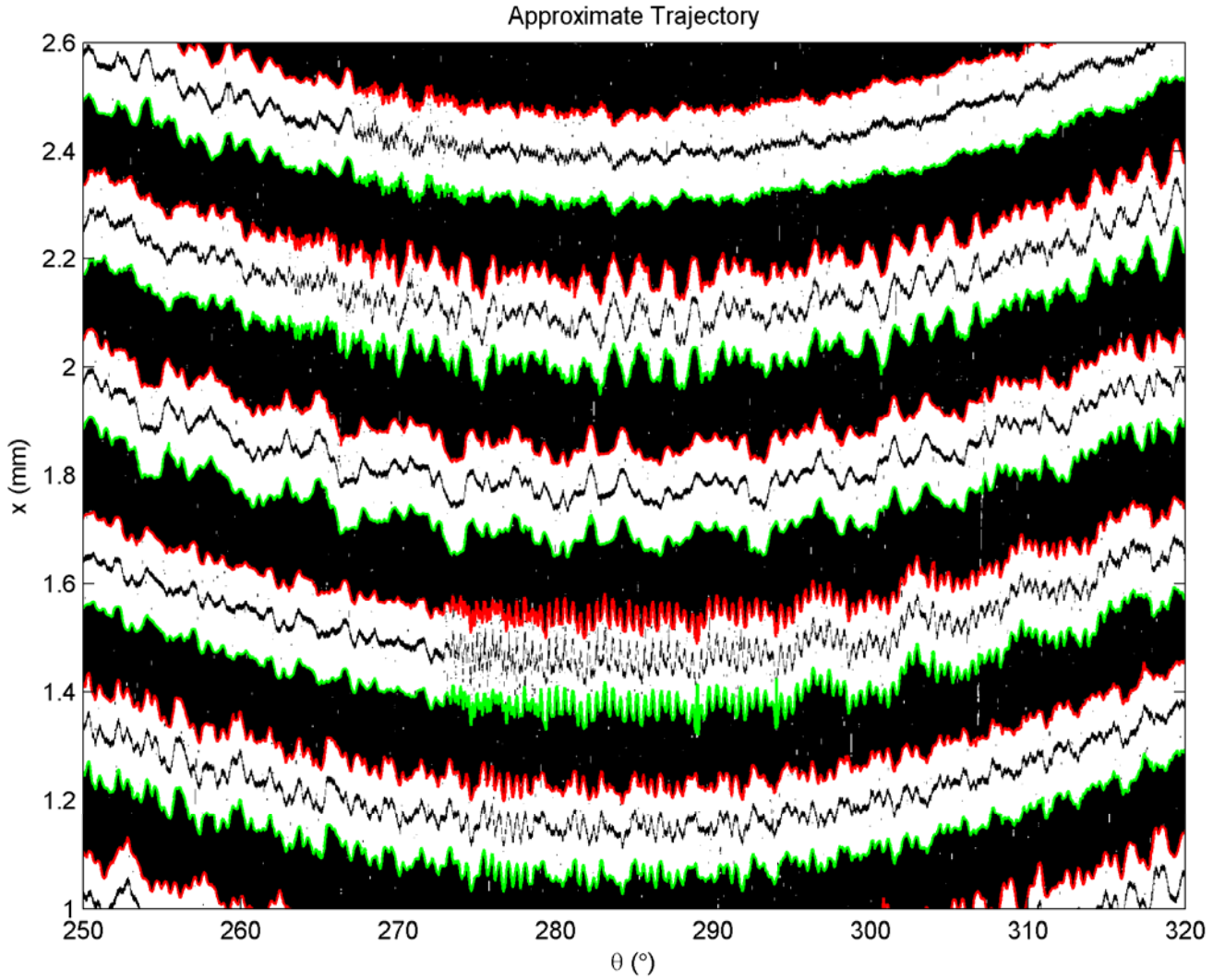

Left Edge Signal

Right Edge Signal

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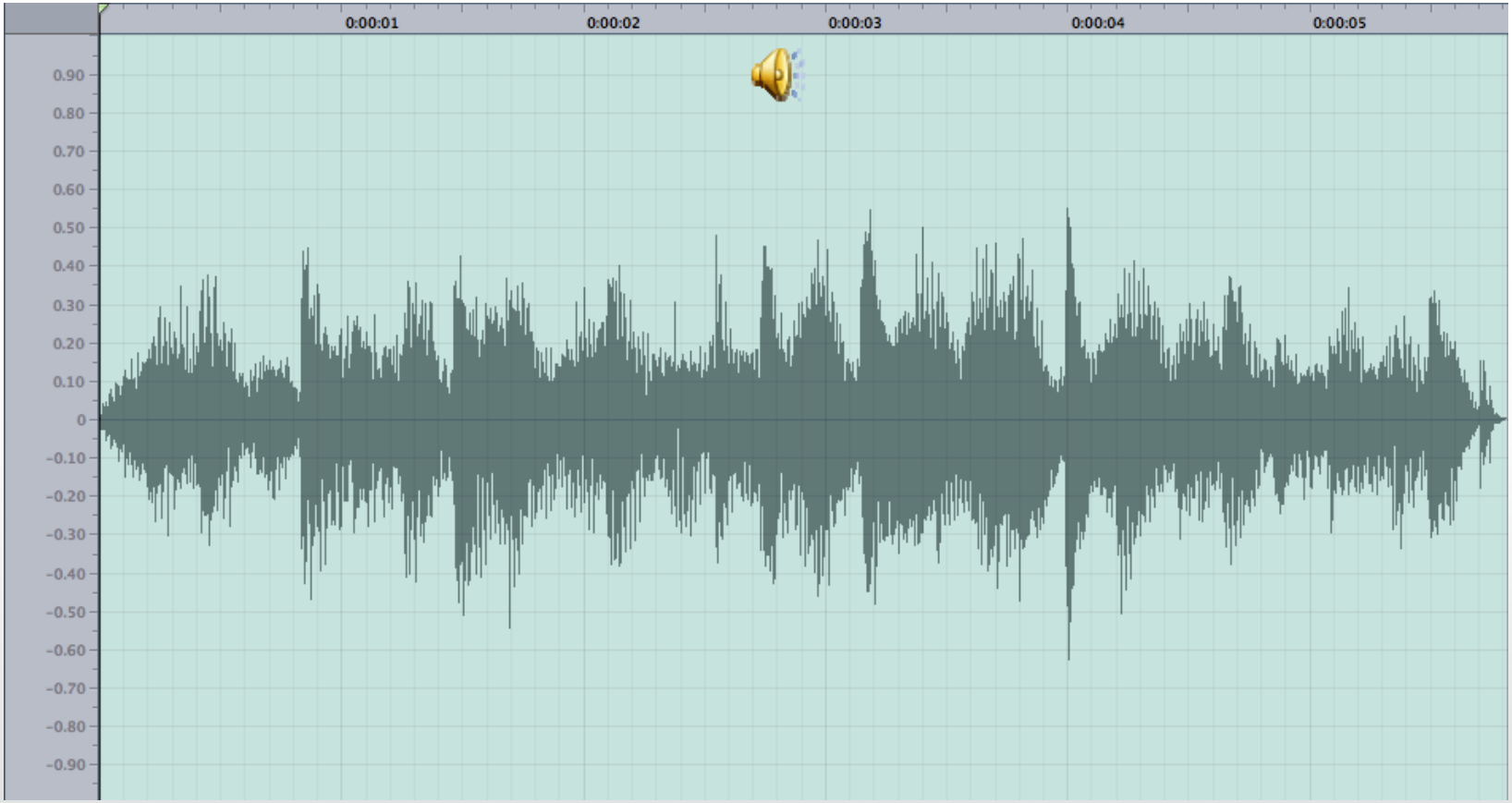
Example Audio



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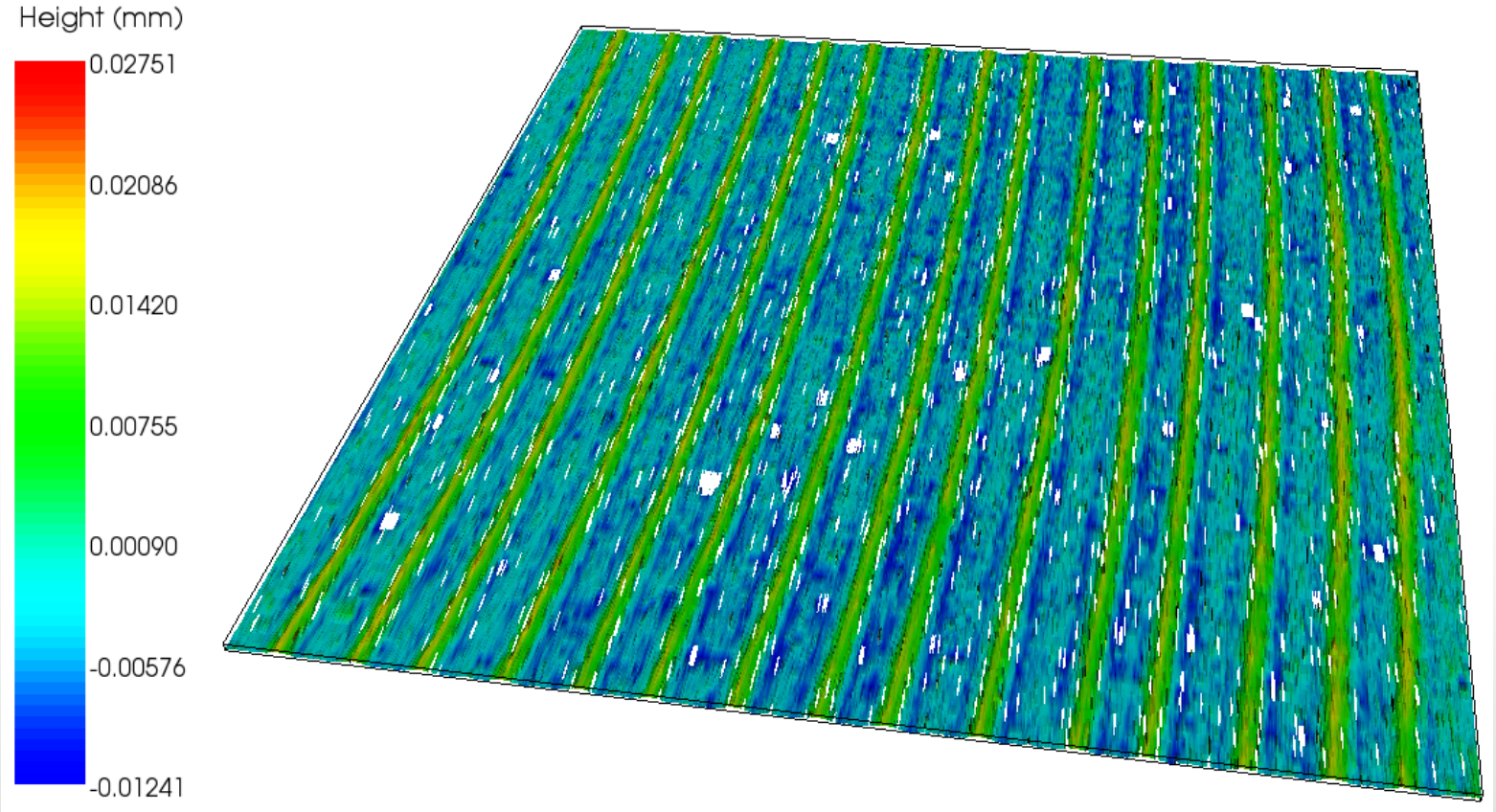
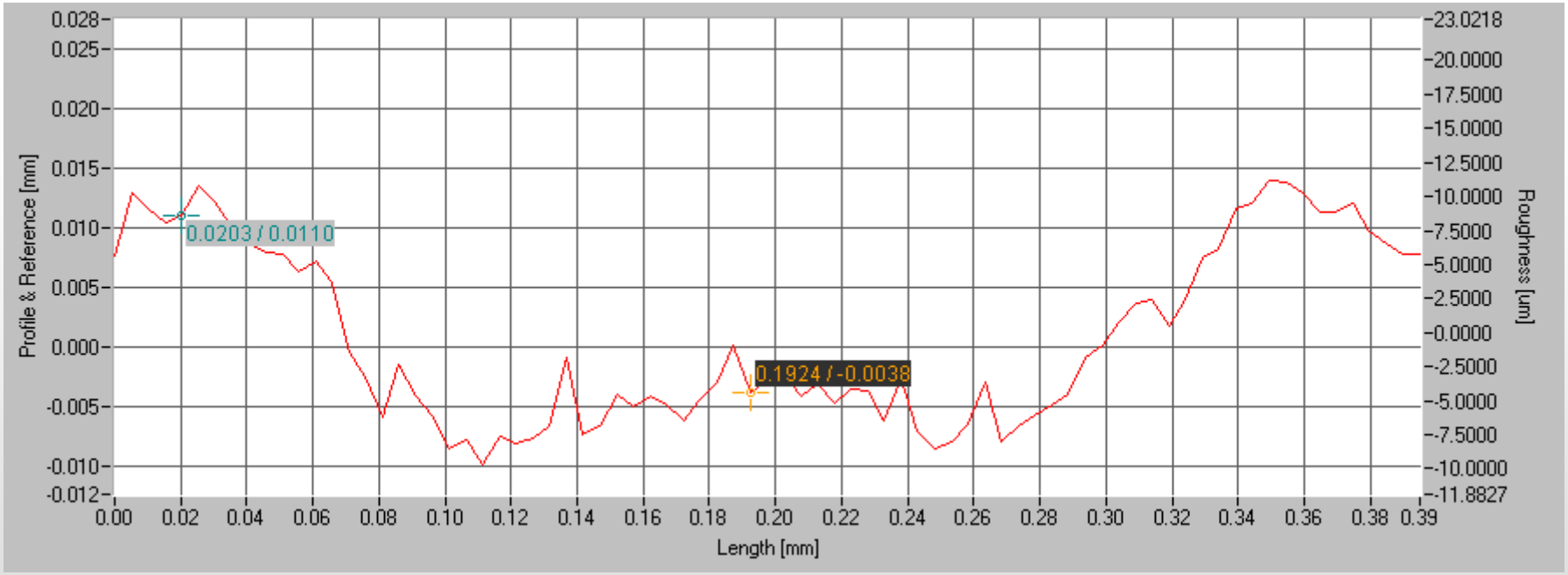
Case Study: Berliner Metallic Master

- One of the EMI archives earliest sound recordings.
- 5 inch Metallic Master Disc
- The earliest disc were 5 inch discs and used for Toy Gramophones, c.1889, according to the USA library congress these are “very rare indeed”.
- Number 87


E. BERLINER's
GRAMMOPHON
No.
Alle Copir-Rechte
vorbehalten.

Inverted data showing groove structure




0.028
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.012
Profile & Reference [mm]
0.0203 / 0.0110
0.1924 / -0.0038
-23.0218
-20.0000
-17.5000
-15.0000
-12.5000
-10.0000
-7.5000
-5.0000
-2.5000
-0.0000
-2.5000
-5.0000
-7.5000
-10.0000
-11.8827
Roughness [um]
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20 0.22 0.24 0.26 0.28 0.30 0.32 0.34 0.36 0.38 0.39
Length [mm]

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Conclusions

- Methods have been developed for sound extraction from full surface scans of cylinders and flat disks
- Numerous audio data streams can be derived from a single surface dataset – suggesting possibility to optimise tracking
- Specially produced test cylinders allow for signal quality analysis of these different signal estimates
- The non-contact method is immune to tracking distortion
- Allows for accurate tracking of damaged groove structures
- Potential to reconstruct badly damaged artefacts

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