Restoring the 1878 "St Louis" Edison Tinfoil Recording

In 1877 Thomas Alva Edison invented the Phonograph. While others had recorded sound before this, Edison was the first to both record and reproduce sound. This invention was transformative. It opened the door to a myriad of applications of signal recording, from the birth of the commercial sound recording industry to a vast variety of scientific and research applications which now form the basis of many modern measurement techniques.

A small number of recordings from this very early period survive to this day. They are delicate artifacts which are effectively unplayable using 20th century record turntables or derivatives and are unlikely to survive any sort of invasive treatment. Among this group of early records is the 1878 "St. Louis" tinfoil which is in the collection of the Schenectady Museum of Innovation and Science (MISCI). This foil has recently been digitally restored and can be played again using 21st century optical methods to non-invasively resolve the detailed structure of the foil itself and computer analysis to determine the recorded audio content.

The tools used to restore the St. Louis tinfoil were developed at the University of California Lawrence Berkeley National Laboratory in collaboration with the Library of Congress. In recent years they have been put to use restoring a variety of key artifacts from the early developmental period of audio recording. These include the first known sound recordings on paper (1860), due to French inventor Leon Scott de Martinville, the experimental recordings of Alexander Graham Bell and Charles Sumner Tainter, from the 1880's, and later experiments of Edison himself. The 1878 St. Louis Edison tinfoil actually completes a historical restoration sequence from the earliest period of sound recording history. It is currently the oldest restored Edison recording which was actually created for reproduction.

What is sound, how was it recorded, and why is it valuable?

Sound is a form of energy which travels through matter by creating a density wave of periodic compressions and rarefactions of the substance. Like the motions of the bottom of a paper cup, when spoken into, Edison transferred the sound wave from the air into a diaphragm and stylus mechanism which then embossed the sound variation into a sheet of moving tinfoil. By effectively reversing the process, Edison could reproduce the recorded sound. Apparently inspired by his experience trying to record discrete telegraph impulses on paper, Edison grasped that he could also capture the continuous effect of sound from a voice. Today we would say that Edison started off recording digitally and then moved to analog signals! Edison submitted his invention as a patent application in 1878. A sketch from that is shown in Figure 1 along with a reproduction of his original device, and an image of the 1878 foil itself. Edison also provided a personal account of the invention in his writings, which are excerpted here:

> "…I designed a little machine using a cylinder provided with grooves around the surface. Over this was to be placed tinfoil, which easily received and recorded the movements of the diaphragm...Kruesi (the machinist), when he had nearly finished it, asked what it was for. I told him I was going to record talking, and then have the machine talk back. He thought it absurd. However, it was finished, the foil was put on; I then shouted 'Mary had a little lamb', etc. I adjusted the reproducer, and the machine reproduced it perfectly. I was never so taken aback in my life. Everybody was astonished. I was always afraid of things that worked the first time…."

When Edison says "I was never so taken aback in my life", we can perhaps partake just a bit in what that experience must have been like. We are so used to hearing recorded sounds today that we may otherwise miss how amazing it would have been to someone in the late 19th century to hear a machine speak back.

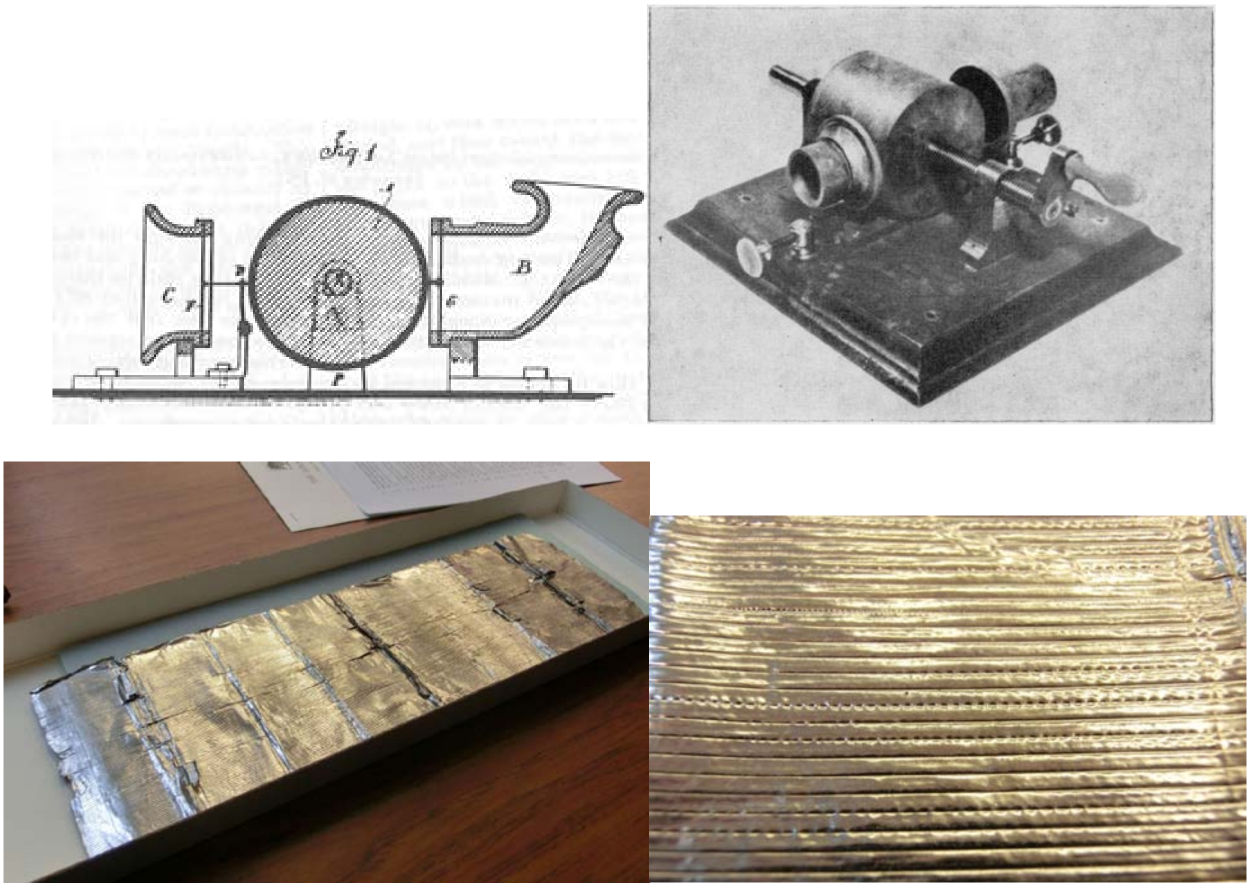

Figure 1: Top left is a sketch from Edison's patent application for the Phonograph. A reconstruction of the original device is at upper right. The 1878 St. Louis tinfoil is at lower left with a detail shown at lower right. The multiple fold marks are visible as well as the detailed groove structure carrying the embossed audio pattern.

As noted already, the recorded artifacts of the 19th century, and actually many from the early 20th century as well, if not unplayable otherwise, can benefit by a modern analytical approach to preservation and access which does not need to invade the delicate surface with a playback stylus. Indeed, these artifacts are numerous and diverse, in character and in content. Today, large and significant collections of historical sound recordings reside in the major archives such as the Library of Congress and the British Library, and in numerous other collections at museums, libraries, and academic institutions worldwide. Among the categories held in these collections are the following.

- Early technical tests and experiments on recording methods.
- Field recordings of linguistic, cultural, and anthropological materials
- Field recordings of sources which underlie much of modern music.
- Speeches & spoken words of historical figures, key musical artists, poets, and writers.
- Early radio broadcast transcriptions.
- Live performances and events.
- Public and private dictation and monitoring records, intelligence, and Presidential sources
- Most commercial record releases

The archives want to both preserve these recordings, to meet the needs of any future interest, and to create broad digital access to the collections.

More than simply a tool to capture spoken words or music, the invention of sound recording should be viewed within the technological context of the 19th century. This was an extremely fertile period for the inventions which ultimately underlie our entire information and communication age. The impact is arguably as significant as the earlier industrial, and coincident transportation revolutions. This period began in the 1820-30's with Niepce and Daguerre's development of photography, continues into the 1870's and 1880's with telegraphy, Bell's telephone, Scott, Edison, and Bell's sound recordings, Muybridge's motion capture, and then wireless communication by Marconi, and vacuum tube rectifiers and amplifiers by Fleming and De Forest. Today's analysis of historical sound recordings sheds lights on this important period in the development of today's technology.

An optical method of sound restoration is applied to the St. Louis tinfoil.

In an optical approach, the stylus is replaced by light. Light which reflects off a surface carries with it information about the shape and structure of the surface. If that information can be recorded with sufficient precision and completeness, it is possible to replace the action of the stylus with that of a mathematical analysis of the light pattern, performed on a computer.

In order to restore the 1878 St. Louis Edison tinfoil, it was brought to the optical sound restoration workshop at Lawrence Berkeley National Laboratory in Berkeley, California, in July of 2012. As part of the larger effort to study early sound recordings many of the tools needed to restore this artifact were already in place. None-the-less the St. Louis tinfoil was unique in a number of regards. The tinfoil had been stored in an envelope with some seven folds impressed upon it, it was not flat, and the original impressions themselves were quite deep compared most other sound recordings encountered previously. A natural approach might have been to again wrap it around a cylinder as Edison had done. In the end however, due to its condition, it was decided to optically scan it on a flat bed. This configuration and the characteristics of the foil meant that the tools had to be adapted for the St. Louis tinfoil. The resulting measurement system is shown in Figure 2.

At the heart of the measurement process were a special microscope which could image the surface of the foil and a precision moving table which positioned the foil at a series of locations under the microscope. A computer gathered data from the microscope and continuously correlated it with the positions of the table.

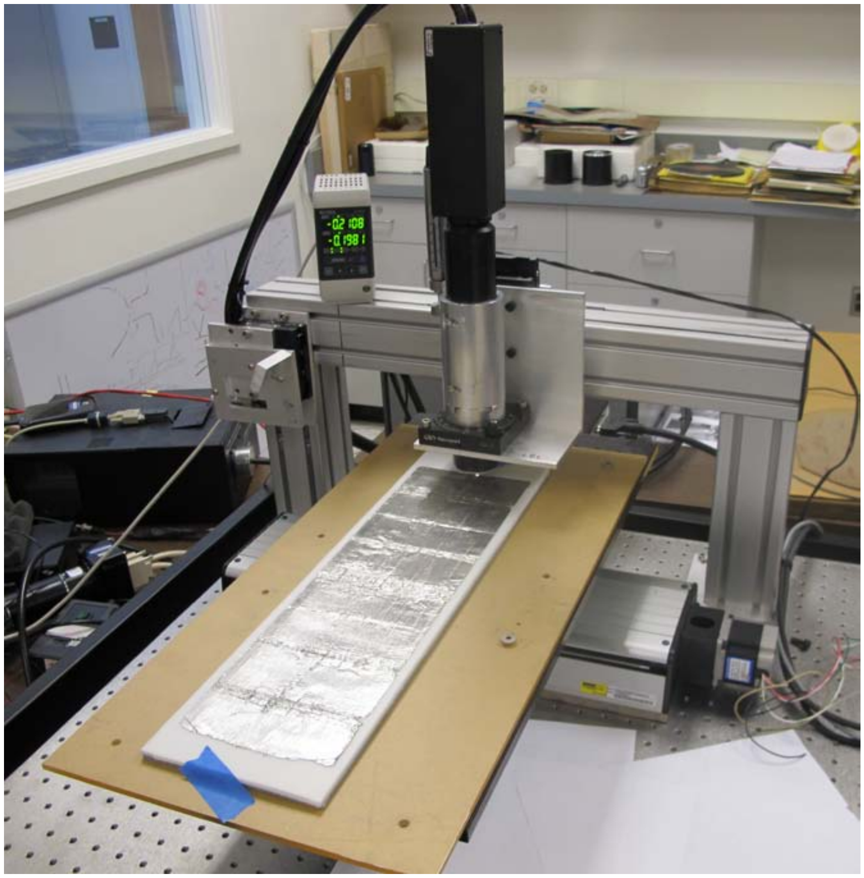

Figure 2: The Berkeley Lab optical scanner holding the 1878 St. Louise tinfoil. The foil is mounted on the flat bed of a computer controlled, two axis movement. One of the scanning stages can be seen protruding from under the bed at right. The optical probe used is the vertically mounted black and metallic object at the center. A light spot can be seen just at the top of the foil.

The embossed groove on an Edison tinfoil encodes the audio information in an up-and-down movement of the surface. Known as a "vertical cut", this is distinct from the usual groove on the later 20th century disc records. There the groove moved from side-to-side. In order to measure a vertical groove, the microscope must be sensitive to depth and that is not what we usually expect from an imaging system. For example, a camera captures, in great detail, the scene in the familiar two dimensions of the frame. It gives little information about the third dimension, into the plane of the image. Beginning in the 1960's a new microscope configuration was realized which traded off the two dimensional detail of a full image, for a powerful capability in the third dimension, albeit on a limited number of points. Known as a "confocal microscope", this device became a mainstay of biological imaging due to its ability to vertically section cells.

At the Berkeley Lab a special type of confocal microscope was employed to scan the St. Louis tinfoil. That microscope measured a cluster of 180 spots along the foil. The spacing between the points was just 10 thousandths of a millimeter and each measurement was accurate in depth to about 100 millionths of a millimeter. To set the scale, that is 250 times smaller than a human hair. This cluster of spots was scanned over the entire surface of the foil. The resulting image had roughly 4000 megapixels! The principle of the confocal microscope is addressed also in Figure 3.

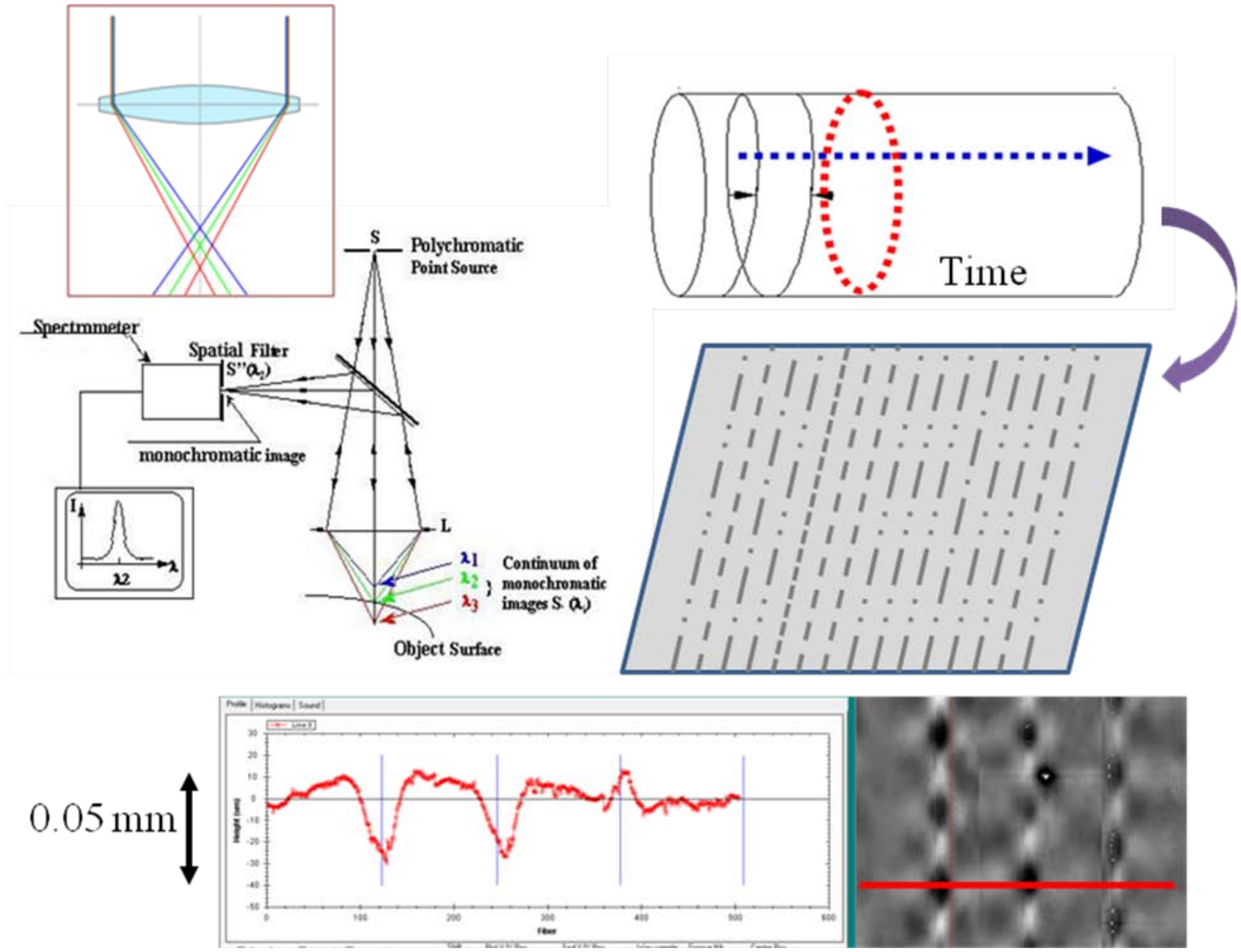

Figure 3: Principle of the (color coded) confocal microscope and its application to the tinfoil recording. The microscope is based upon the effect of chromatic aberration, wherein a lens acts partly like a prism by focusing the different colors of light at different points along the axis. This is shown at the upper left. The microscope, shown at middle left, can detect precisely which color is in focus at any moment and correlate that with the depth of the surface which is being illuminated. The tinfoil is normally wrapped around a cylinder, as shown at the upper right. The embossed groove runs as a helix around the cylinder. Once the foil is unwrapped and laid flat, the grooves become parallel diagonal lines which are then imaged by the microscope. A tiny portion of the measured foil is shown at the bottom of the figure. At lower right is a depth image, darker is deeper into the surface. The horizontal red line refers to the profile shown at lower left. The typical groove depth here is 0.05 millimeters.

Once this detailed image was acquired, it was processed and analyzed by a computer program which had been previously developed as part of the broader effort to study early sound recordings. The program traced the pattern a stylus would have followed and calculated, at each point in time, the motion, up-and-down, and the speed the stylus would have had. When the program encountered small regions of damage, dirt, or tears it was capable of "fixing" them automatically, similar to "Photoshop". As can be seen in Figure 1, lower left, sometimes the damage was not small. In particular the regions of the seven folds were very irregular and degraded. In the end there was sufficient damage there to fundamentally degrade the recording. Fortunately the folds are distinct with lots of good audio in between. Once the stylus path was calculated another mathematical procedure was used to convert that motion description into audible sound and produce a digital sound file.

Some features of the St. Louis tinfoil can be seen in Figure 4 which is also derived from the computer analysis. This is a "depth" image where dark means relatively deeper into the surface of the foil. The embossed structure is clearly resolved in this image.

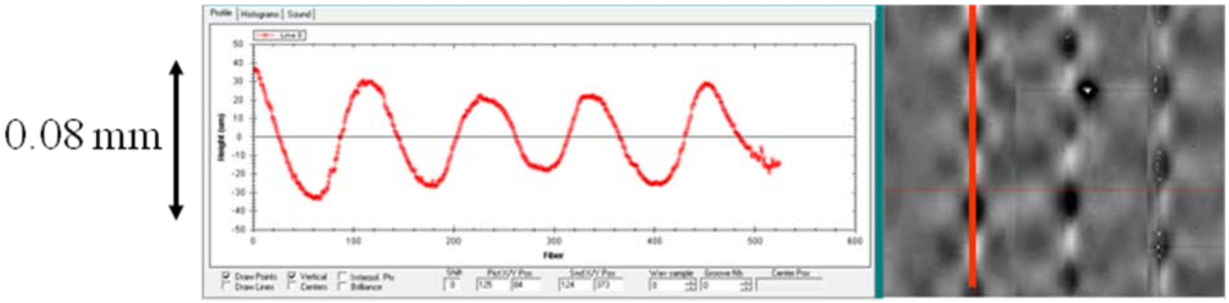

Figure 4: A different view of the foil surface. Here the red line runs in the direction of the audio track. The recording and playback stylus would move from top to bottom in this image. The reconstructed stylus motion is shown at left.

The St. Louis foil itself and its significance.

The resulting sound file will be presented in public on October 25, 2012, in Schenectady. The recording is an interesting combination of music and spoken words. It begins with an apparent brass duet of an unidentified melody. This must be the oldest reproduced recording of instrumental music. What follows is a recitation of "Mary Had a Little Lamb" and "Old Mother Hubbard", the nursery rhymes, as well as laughter. The foil would have been wrapped around a cylinder during recording and playback. The flat sheet scanned at Berkeley would have had its top and bottom edges in contact. Each pass along the groove now crosses the seven folds and the seam. This results in a very regular pattern of eight repeating "thumps" for each effective rotation of the foil. This can be seen in a portion of the audio waveform which is shown in Figure 5.

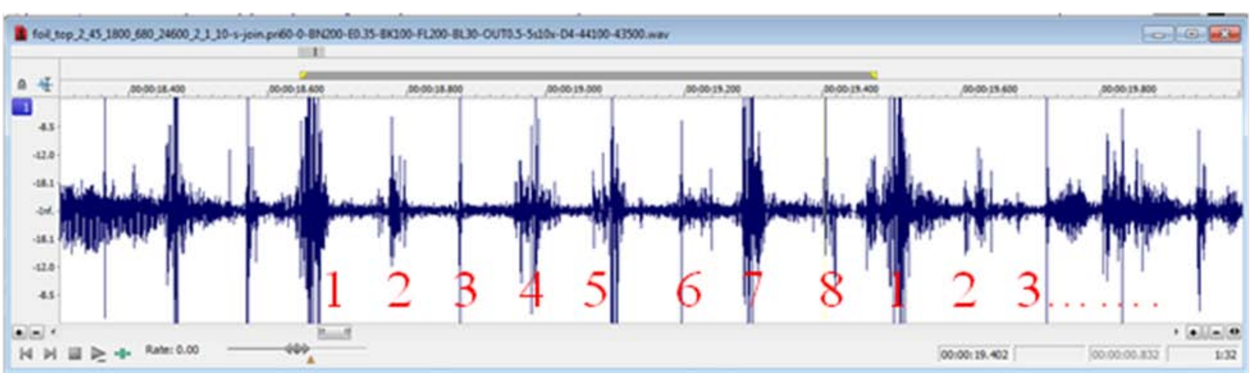

Figure 5: About 1.6 seconds of the audio waveform with the 8 fold "thumps" marked out.

Restoration of any sort of artifact is not a completely objective process. The workers invariably make choices of how far to take the effort. A perspective largely adopted here is that of minimalism. The approach is to leave as much of the information intact even if that means noise degradation may relatively worse. It is often possible to apply further filters and other modifications to a digital file in a discretionary effort to further improve or effect the final result.

Coming back to the greater context of the early years of sound recording and beginning of modern information and communication technology, the methods described here have also been applied to a variety of other collections as mentioned already. Of note are the 1860 Leon Scott paper tracings, the first surviving disc record, by Bell and Tainter, and Edison's early talking doll experiments. Moving into the 20th century work is ongoing with important ethnographic field recordings of Native Americans and Canadians, and of South Slavic folklore. But the 1878 St. Louis Edison tinfoil is a singular event because it really represents our closest approach to the beginning of recorded sound as we have come to know it as a culture and a nation.

The restoration project on the 1878 St. Louis Edison tinfoil recording was performed by Earl Cornell and Carl Haber of Lawrence Berkeley National Laboratory, Mark Guadagni. an undergraduate student at the University of California, Berkeley, and Chris Hunter, of the Museum of Innovation and Science (miSci), Schenectady, New York.

Additional information about the Berkeley Lab sound recovery project is at http://irene.lbl.gov/

Berkeley Lab is a member of the national laboratory system supported by the U.S. Department of Energy through its Office of Science. It is managed by the University of California (UC) and is charged with conducting unclassified research across a wide range of scientific disciplines. The Lab website is http://www.lbl.gov/

Carl Haber
Senior Scientist
Physics Division
Lawrence Berkeley National Laboratory
chhaber@lbl.gov
510 529 5934

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