A physicist uses X-rays to rescue old music recordings

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Sebastian Gliga winding a tape on a Studer A80: The tape machine is on loan from Idee und Klang in Basel, the studio of sound engineer and composer Daniel Dettwiler. The analog device, which was manufactured in Regensdorf in the 1970s, serves to produce reference recordings that can be directly compared with the results of the synchrotron measurements. Credit: Paul Scherrer Institute/Mahir Dzambegovic

Researchers are developing a technique that uses the special synchrotron X-ray light from the Swiss Light Source SLS to non-destructively digitize recordings from high-value historic audio tapes—including treasures from the Montreux Jazz Festival archive, such as a rare recording of the King of the Blues, B.B. King.

Magnetic tapes have almost completely disappeared from our lives and now only enjoy a nostalgic niche existence. However, significant quantities of these analog magnetic media are still stored in the archives of sound studios, radio and TV stations, museums, and private collections worldwide. Digitizing these tapes is an ongoing challenge as well as a race against time, as the tapes degrade and eventually become unplayable.

Sebastian Gliga, physicist at PSI and expert in nanomagnetism, and his team are developing a method to non-destructively digitize degraded audio tapes in the highest quality using X-ray light. To achieve this goal, they have been collaborating with the Swiss National Sound Archives, which has produced custom-made reference recordings and provided audio engineering know-how. Now, a partnership with the Montreux Jazz Digital Project will help to further develop and test the method.

Saving audio tapes from decay

The remaining members of the famous rock band Queen recently faced a big challenge. In their studio, the musicians found a tape from 1988 containing a song with the voice of their legendary singer Freddie Mercury, who died in 1991. However, the tape was badly damaged. At first, no one believed they would be able to save this special piece. With great effort, the sound engineers managed to succeed after all.

"It's like stitching pieces together," guitarist Brian May told the BBC. On 13 October 2022, the song "Face It Alone" was finally released and stormed the worldwide charts, more than 30 years after its original creation.

"This example shows that tapes are not made to last forever," explains Gliga. "The material decays over time and can no longer be played back." While it is possible to painstakingly reassemble and restore such tapes, Gliga and his team are pursuing a completely new approach. They use synchrotron radiation: "With X-ray light from a synchrotron, we can reconstruct even heavily damaged tape fragments without even touching them."

A unique concert recording of legendary blues guitarist B.B. King is currently sitting on Gliga's lab bench. In 1980, the King of the Blues played his second concert at the Montreux Jazz Festival—a 48-minute spectacle that was captured on tape by Swiss sound engineer Philippe Zumbrunn. Today, however, only about ten seconds of this recording can be played back at a time. The chemical composition of the tape has already decayed to such an extent that any playback on a conventional device will only further destroy the tape.

"We were not only interested in the musical content of this B.B. King recording, but also in taking on the challenge its state of decay presents," states Gliga. "Synchrotron radiation may overcome the limitations of conventional restoration methods."

Reading the magnetic states

Audio tapes store information in a layer of tiny magnetic particles—like little compass needles pointing either north or south. When the tape is recorded, their magnetic orientation is changed—the tape becomes magnetized, and the audio information is now physically stored in the orientation pattern. To play back this pattern, the tape is moved past a play head. As the magnetic field constantly changes through the pattern, a voltage is induced in the play head and an electrical signal is generated. This signal is amplified and converted into an acoustic signal.

With his X-ray method, Gliga does not rely on the magnetic field, but on the individual compass needles that generate this field. "The magnetization states of these tiny particles, whose size is smaller than a tenth of the diameter of a human hair, can be read out almost individually using the X-ray light of the SLS and converted into a high-quality audio signal," he says.

The most accurate copy

"Digitization is a continuous process," explains the physicist. The so-called sampling rate is important. The term refers to the frequency at which an analog signal is sampled for conversion into a digital signal. The continuous sound wave is divided into segments of a certain time interval and stored digitally. A higher sampling rate means a higher resolution in the digitization of the original signal.

Since the synchrotron light can measure almost every single magnetic compass needle on the tape, it can achieve unprecedented resolution. "We achieve something like the most accurate copy," Gliga explains.

Nostalgia meets high-tech

Much of the audio world is physics and can be expressed in formulas and numbers. However, when it comes to concepts such as sound and the quality produced, the subjective aural experience is paramount. That is why Gliga works with experts like the Basel sound engineer and composer Daniel Dettwiler. Dettwiler is renowned for analog music processing. His studio is also home to a Studer A80, a tape machine that records and plays back magnetic audio tapes with high precision.

"What we reconstruct with X-rays is the raw audio signal as it is stored on the tape," explains Gliga. However, if you play the same tape on the Studer, you get a slightly different signal. "This is due to the electronics inside the device, which additionally process and manipulate the sound." Gliga and his team therefore use this analog device from the 1970s to compare the sounds extracted at the synchrotron with the conventionally digitized pieces.

At the moment, however, the synchrotron light remains off—it is "dark time" at the SLS. The large research facility is undergoing a comprehensive upgrade between now and the beginning of 2025. The aim is to improve the brilliance of the synchrotron beam by a factor of 40.

"Our method will benefit greatly from the upgrade, and it will enable even more efficient measurements," explains the physicist.

Provided by Paul Scherrer Institute

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