Experiment Report

Proposal ID and Title: HG-266 "Remaster Faster: Fast readout of historic audio recordings with RIXS-MCD"

Beamline	Scheduled Shifts	Session Start Date	Session End Date
ID20	18	24/02/2026	02/03/2026
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Local Contact(s)	DETLEFS BLANKA, SAHLE CHRISTOPH		

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<table>
<tr><td>ESRF</td><td colspan="2">Experiment title:
Remaster Faster: Fast readout of historic audio recordings with RIXS-MCD</td><td>Experiment number:
HG-266</td></tr>
<tr><td>Beamline:
ID20</td><td colspan="2">Date of experiment:
from: 24/2/2026 to: 2/3/2026</td><td rowspan="2">Date of report:
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Received at ESRF:</td></tr>
<tr><td>Shifts:
18</td><td colspan="2">Local contact(s): C. Sahle / B. Detlefs</td></tr>
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Report:

Summary:

In this experiment, we aimed to increase the readout speed from historic magnetic analogue audio tapes utilising our novel dispersive resonant inelastic X-ray spectroscopy (RIXS) technique and the high photon flux available at ID20. By generating circularly polarised X-rays using the diamond phase plate and exploiting the X-ray magnetic circular dichroism (XMCD) effect, the orientation and strength of the magnetic domains within the tapes can be measured with 1s2p RIXS. Utilising our custom tape transport, we scanned the tape at a fixed speed while simultaneously measuring the magnetic signal with a continuously triggered detector. This enabled us to measure much longer segments, as we were previously limited by both the 2cm travel distance of the stage and the deadtime for point-by-point acquisition. We used this setup to optimise the measurement parameters, such as the step size, integration time, and incident X-ray angle, measured on segments of 1, 5, and 8kHz test tones. Ultimately, we measured 3.7s from B. B. King's 1980 concert with two different sets of measurement parameters. This will allow us to develop specialised denoising tools to further improve the measurement speed. The total of 7.4s of measured audio represents a dramatic improvement on what was possible to measure until this point, laying the groundwork for the realistic recovery of degraded audio recordings.

Results:

In HG-244, we were limited by the maximum amount of tape we could measure at once, due to the limited space around the endstation limiting the lateral travel of any stage to a few cm. In contrast, each second of audio corresponds to 38.1 cm of tape. To overcome this limitation, we developed a custom tape transport setup, shown in *figure 1*. The main reel (centre) pulls the tape at a constant angular speed using an encoded rotation stage with 20 nm (0.000'043 degree) accuracy. The second reel (right) holds the audio tape and is connected to a closed-loop feedback tension system to ensure the tape is smoothly unspooled. Incident circularly polarised X-rays from the synchrotron are microfocussed onto the tape (red arrow) and are then scattered by the tape and enter the detector chamber (yellow arrows). The reel moves at a constant angular velocity, which translates into the linear velocity of the tape at the measurement position to better than 1% across the total length of the measurements here. Continuous scans were implemented by the beamline team so that the tape could be measured while moving at constant speed with no deadtime. This led to a 2x speedup compared to our previous measurements.

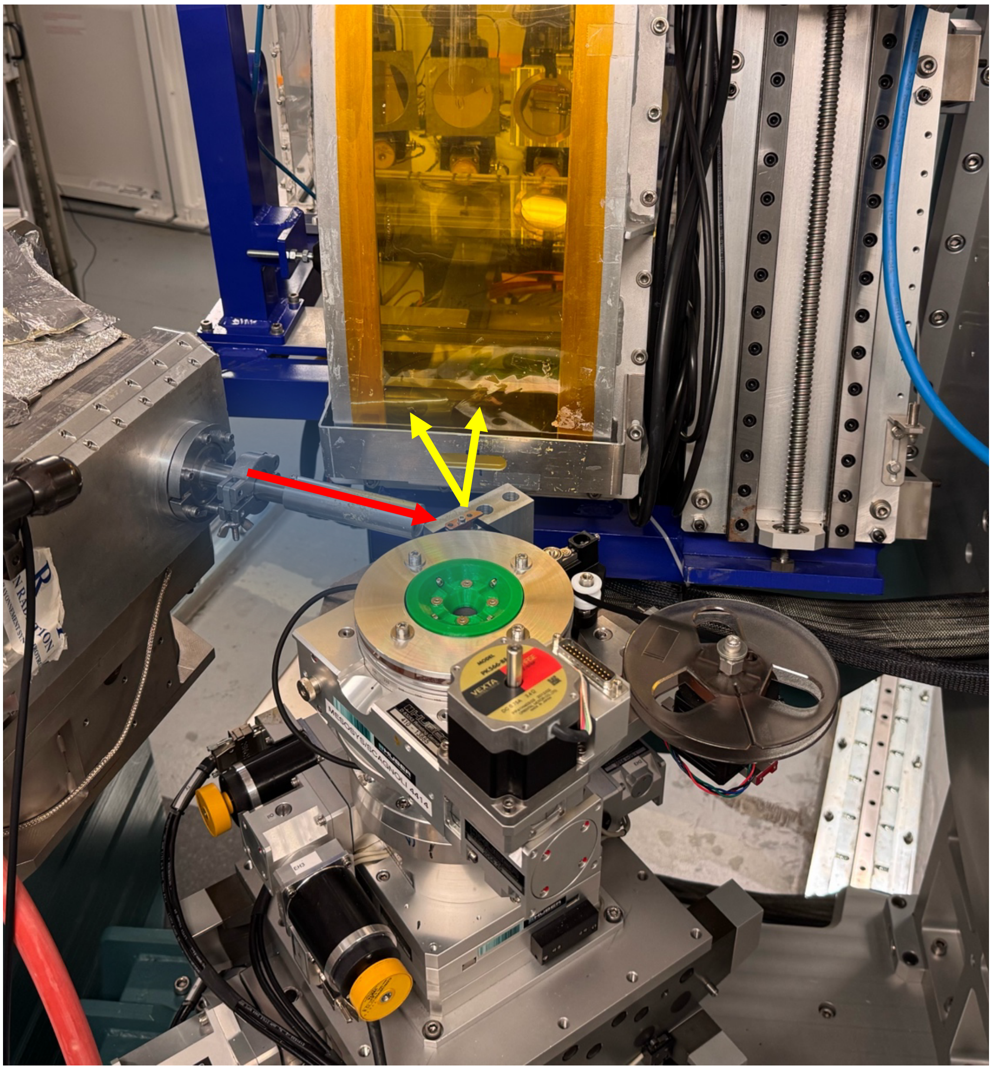

Figure 1: Picture of our custom tape transport system at ID20.

To determine the optimal readout parameters, primarily the incident X-ray angle on the tape and the integration time per point, we measured tapes containing test tones with frequencies 1, 5, and 8 kHz. Three example measurements are shown in *figure 2* for a 1kHz tone. We found that a 40° incident angle and 0.5s integration time per point were the best compromise between the highest measurable audio frequency and signal-to-noise ratio while allowing us to measure the desired amount of audio from the B. B. King recording.

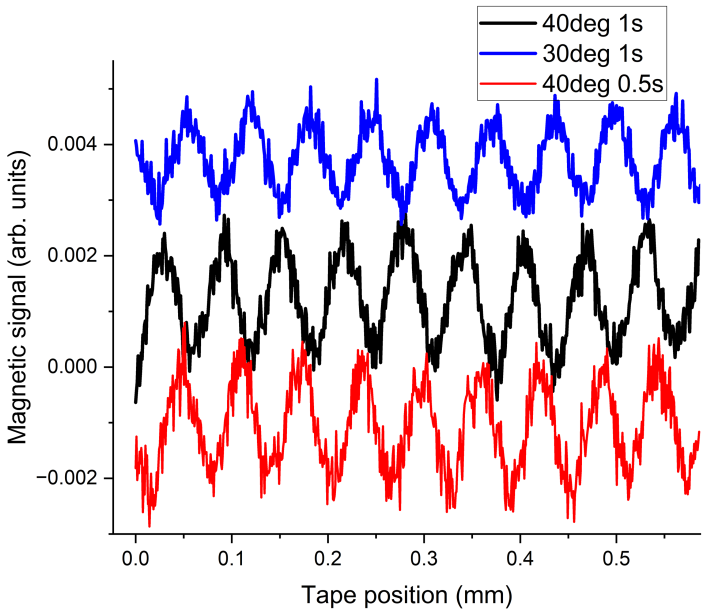

Figure 2: XMCD measurement of a 1kHz test tone with different incident X-ray angles and integration times.

Following this optimisation, we measured 3.7s from B. B. King's 1980 concert at the Montreux Jazz Festival (see *figure 3*). This represents a **ten-fold increase** over the total audio measured during the previous experiment and is a major milestone for the project. A segment of the recovered audio is shown in figure 3, alongside the original recording. We are currently working on tools to denoise the data in collaboration with RTS (Radio Télévision Suisse). A challenge is the fact that the dominant contribution to the noise comes from the (Poisson) counting statistics of the X-ray detector, whereas existing audio denoising tools are optimised for Gaussian noise.

A publication is in preparation based on these and previous results (proposal HG-244) at ID20. The development of denoising tools is a part of the ongoing Master's thesis of Lorenzo Terna (Politecnico di Torino).

These measurements lay the foundation for the development of a custom spectrometer for X-ray tape digitisation in collaboration with the ID20 beamline.

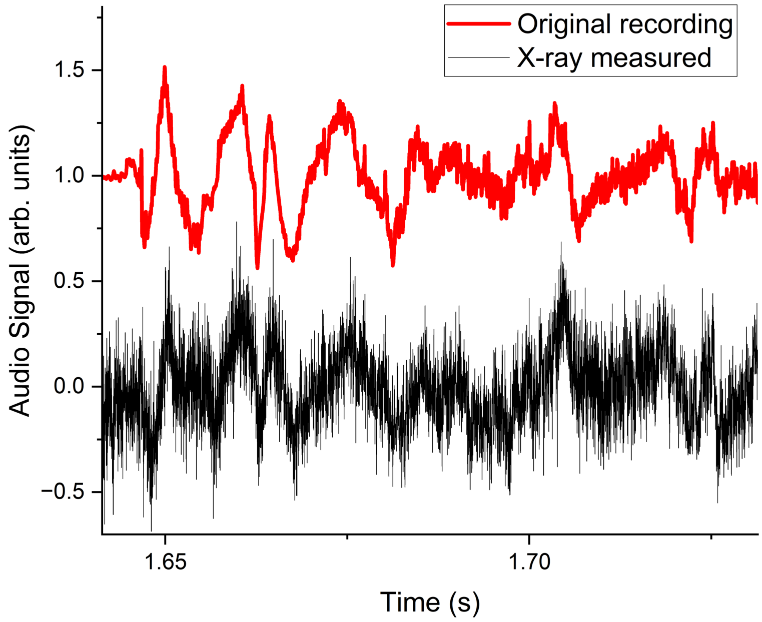

Figure 3: Original audio from a segment of the B. B. King recording (red) and the X-ray recovered audio (black).