Conclusions

This master project focussed on ultrafast electron diffraction which provides a direct analysis of laser-induced structural transitions.
We studied how to measure the time resolution of the system and optimized it for measurements in transmission or reflection. A theoretical model, on the basis of the Two Temperature Model, has been introduced to explain the experimental data.

- Experiments were conducted on nanoparticles of cobalt, on a 45 nm thick film of chrome and gold (5 nm Cr 40 nm Au), and on a silver (111) bulk crystal.
- Although these samples have no structural transitions of great physical relevance, in all cases it was possible to observe the weakening of the diffraction peaks after the laser excitation due to heating (Debye-Waller effect).
- In all three cases, the results were found to be in agreement with the theoretical models, which is a clear evidence of the proper functioning of the experimental setup.

The results are very encouraging for future experiments, as they have shown that the system is capable of a sub-picosecond temporal resolution and of reliably recording intensity changes of the diffraction spots with a signal to noise ratio that allows to analyse signals of amplitude smaller than 0.5%.

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University of Groningen
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for Advanced Materials

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Ultrafast Electron Diffraction of Thin Metal Films and Metal Nanoparticles

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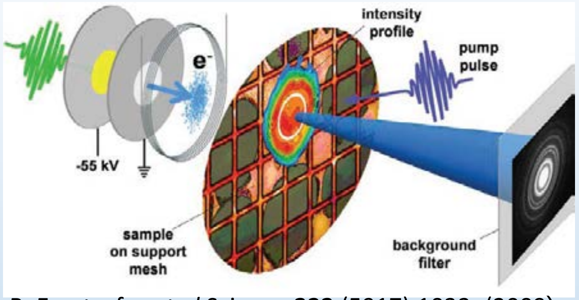
Introduction

One of the open challenges in physics nowadays, is the real-time study of processes that occur at the atomic scale. There is a wide range of poorly understood behaviours, such as simultaneous structural and electronic phase transitions, in condensed matter physics; reaction pathways, in chemistry electron-phonon coupling phenomena, etc..
Ultrafast electron diffraction (UED) is a pump-probe technique, which allow to study structural transitions, induced by photo excitation, at the atomic scale with picosecond time resolution.



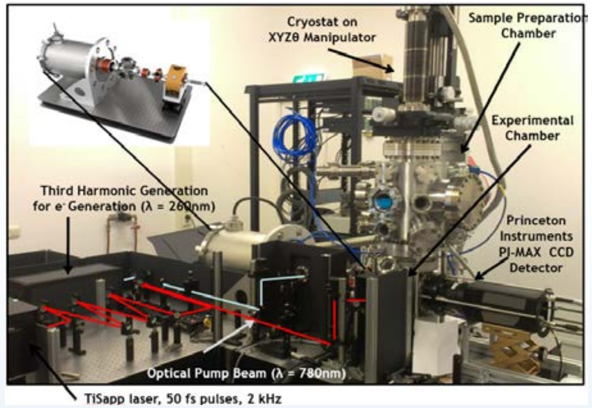
R. Ernstorfer *et al*,Science **323** (5917),1033 (2009).

Purposes

The aim of this thesis is to complete the calibration of the UED system and run the first experiments to ensure its proper functioning. Furthermore, a theoretical model, on the basis of the Two Temperature Model, has been adapted to our experimental data.

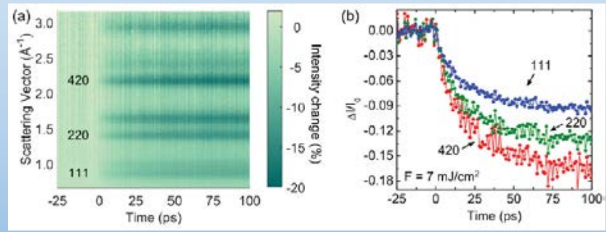
Experimental System

The laser-pump electron-probe experimental configuration, as shown in figure, includes a laser system (2 kHz, 780 nm, 45 fs, 2 mJ/pulse); an electron gun where electron pulses are generated from an photocathode by ultraviolet pulses; magnetic lenses; a RF compressor; a sample holder (with a a cryostat) attached to a 4-axial manipulator; and an imaging system.



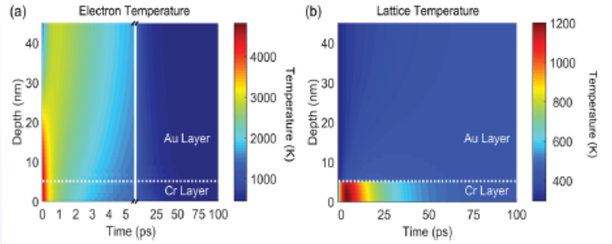
Experiments are performed under UH vacuum conditions with a background pressure of less than $5 \cdot 10^{-9}$ mbar. The UHV chamber is equipped with a sputter gun, two evaporators and an X-ray photoemission spectrometer for sample preparation and characterization. Specimens can be analyzed both in reflection and transmission.

UED studies of a thin CrAu film



In the figure above the changes in diffraction intensity, $\Delta I(S,\ t)/I_0(S,\ t)$, between the pumped (the laser hit the sample) and the unpumped (no laser on the sample) immages are shown. From this we can point out that:

- The magnitude of the drop of the peak intensities coincides with what is expected for the final temperature calculated by simulation.
- Before T_0, the intensity change is $\sim 0\%$. This is indicative of the fact that the sample recovers fully in the 500 μs between the laser pulses.
- Fitting the data with a double exponential, it became clear that there is a fast process (τ_1 = 3±0.5 *ps*) comparable with what is expected for a pure Au foil, and a slower process (τ_2 = 26 ± 4 *ps*).



A simulation (figure above), of the temperature evolution in a CrAu film hit by a laser, was made to explain the experimental data. The fast intensity drop corresponds to the spread of hot electrons into the gold and subsequent excitation of phonons via electron-phonon coupling. The slow process corresponds to the heating of the Au film due to the transfer of energy between Cr and Au. Setting the thermal conductance of this interface (G_I) as a free parameter, we could fit the experimental data (see figure below). This result was obtained for G_I = 650 $MWm^{-2}K^{-1}$ (at 300 K).