Short Visit Scientific Report

30 July 2012

Project: “Detection systems for time resolved MOKE studies in magnetic films and nanostructures ”

Period: 2012 July 2-14

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1. Purpose of the Visit

The main purpose of the visit was to initiate collaborative links between our newly developed laboratory at the University of Porto (IFIMUP-IN and Department of Physics and Astronomy) and the Radboud University of Nijmegen in the area of magnetisation dynamics using ultrafast optical pump-probe spectroscopies.

We have recently concluded the first phase of the establishment of an ultrafast facility for the measurement of magnetization dynamics. This unique system will be used to initiate research into ultrafast magnetization processes provoked by femtosecond laser pulses. Since we have recently developed this system, it would be very useful to exchange researchers with a well-established laboratory to allow knowledge transfer and initiate some studies in ferromagnetic systems using our unique laser source.

It was therefore proposed that I make a two-week visit to the group of Prof. Theo Rasing and Dr Alexey Kimel. In this two-week period a study was made of the detection systems for the MOKE (magneto-optic Kerr effect) measurement, which assisted in knowledge transfer between our groups. Furthermore, the visit allowed us to establish research collaboration for the study demagnetization in ferromagnetic films.

2. Work carried out

In the following we present the work carried out during this two-week stay, as well as the suggestions to our set-up. In the first week I developed a set-up, similar to a pump-probe experiment, to measure the autocorrelation signal of the two beams from the same ultrafast optical pulsed source. In the second week I studied the MOKE signal detection and acquisition system in one of the pump-probe setups at the host laboratory in Nijmegen.

2.1 Week 1

During this first week I designed and implemented a set-up (see Fig 2.1.1.), similar to a pump-probe setup, to measure the autocorrelation signal of the two beams, generated by the nonlinear process of second-harmonic generation (SHG).

The beam is split into a fixed path beam (future probe) and a variable path beam (future pump) using a beam-splitter. The fixed path beam travels a known and constant distance, whereas the variable path beam has its path length changed via a translation stage (delay-line). Both beams are crossed inside the SHG crystal and must be focused at the same point as the delay is scanned, in order for the second harmonic to be generated. The autocorrelation term of the output is then passed into a photomultiplier detector and measured.

This technique provides a reliable way to find the spatial and temporal overlap of the two beams in a pump-probe set-up.

i) The laser system used in this set-up:

- Oscillator Ti:Safira Mira, modelo 900-f, Coherent: 720-900nm (centred 800nm), 100fs, 82 MHz;

ii) The set-up:

- SHG crystal; BG-39 filter;
- Pump and probe lenses: F=10;
- beam-splitter; polarizers;
- translation-stage (delay-line).

iii) The detection and acquisition system:

- Chopper (freq 165 Hz), model SR540, Stanford Research Systems;
- Lock-in, model SR510, Stanford Research Systems;
- photomultiplier detector ;

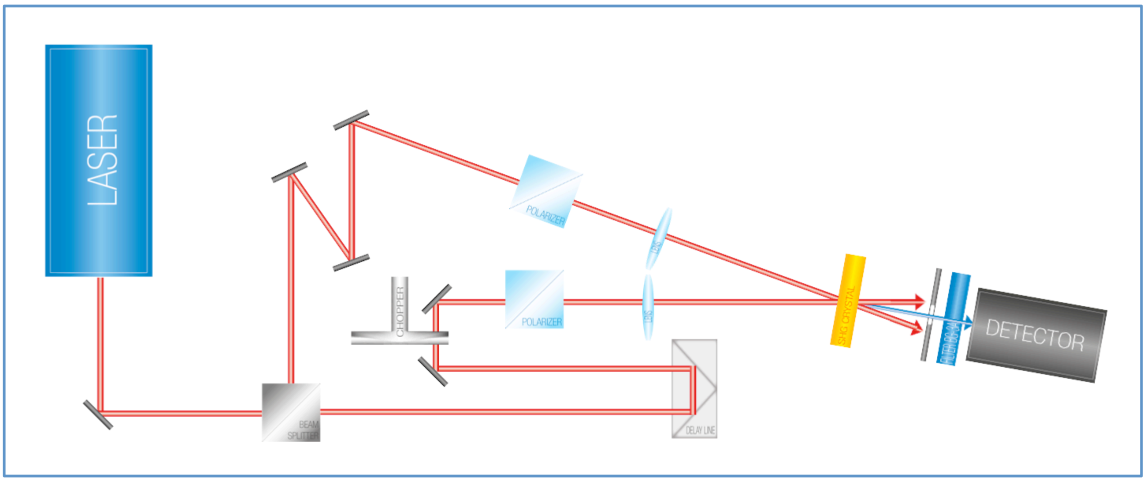


Fig. 1. Schematic diagram of the autocorrelator set-up.

2.2 Week 2

During the second week I carried out a study of their detection and acquisition systems in one of their pump-probe set-ups. I changed the configuration to pass it to reflection pump-probe set-up.

i) The laser system, Spectra-Physics:

- Oscillator, model Tsunami: 82 MHz, centered at 800 nm;
- Amplifier, model Empower: pulse energy 2.2 mJ, 1 kHz, adjustable pulse durations ~ 50 fs to several picoseconds;
- Ultrafast Optical Parametric Amplifier, model OPA-800C: converts the output laser pulses from the amplifier to tunable pulses of wavelength of 300 nm - 3 μm, duration ~ 100 fs.

ii) The pump-probe set-up and signal detection and acquisition system:

The system is a two-colour pump-probe set-up (pump with ~800nm and probe with ~520nm from OPA), see Fig.2., which allows them to eliminate the pump contamination with colour filters as BG39 from Shott. To change the fluence of the pump beam, a change is made in the amount of neutral density filter used before the sample or by changing the spot size at the sample position by moving the lens. The electromagnet system is equal to ours, the only difference is the poles of the magneto (model 3470 from GMW) that have a longitudinal hole. This is used for making Faraday (transmission) instead of Kerr (reflection) measurements.

iii) The signal detection and acquisition system:

- Lock-in, model SR830, Stanford Research Systems;
- Chopper (500 Hz), model MC2000, Thorlabs;
- Home-built balanced detector: has a Wollaston prism integrated in the detector, so is not necessary to have an analyzer before the detector to separate the s and p polarizations of the reflection probe beam; there are four possible outputs: A, B, A+B and A-B.

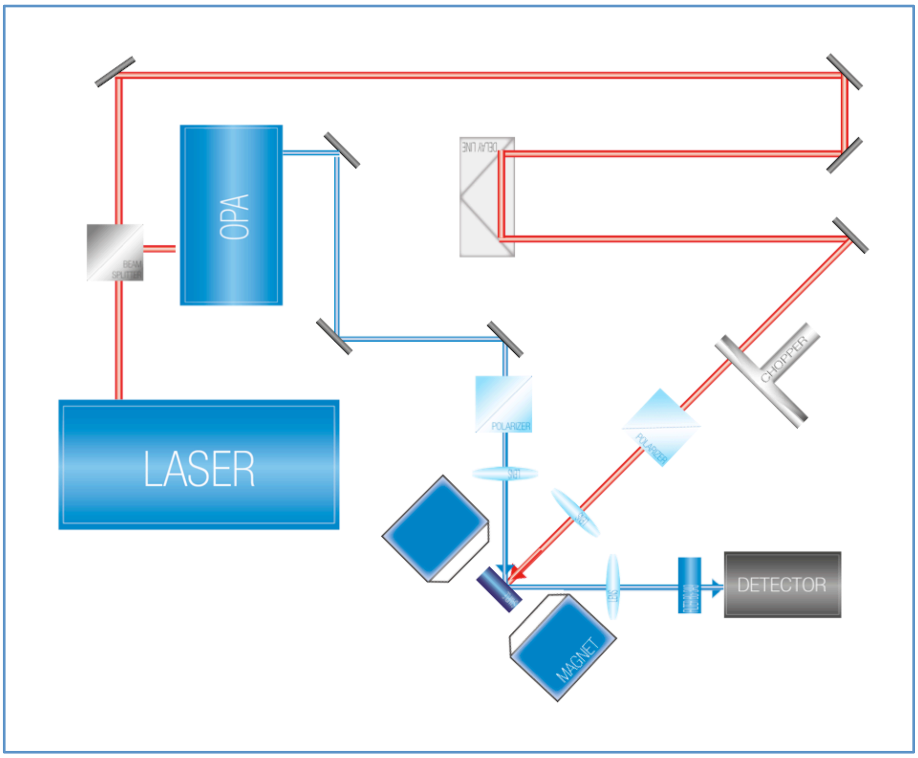


Fig. 2. Time-resolved pump-probe set-up.

iv) The suggestions to our pump-probe set-up:

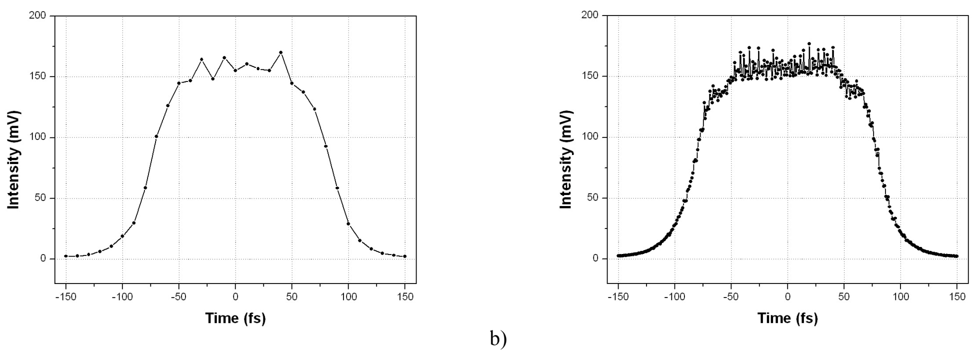
- In order to minimize the pump beam contamination, one rotates the polarization of the pump beam until the s and p components are balanced in the detectors thus their contribution will be cancelled in the difference signal;

- Pass the set-up to a two-colour pump-probe experiment, for instance using a crystal, such as BBO, to generate a second harmonic at the pump beam;
- Use of averaging with several pulses (samples) in the Boxcar Averager improve the signal-to-noise ratio until we change to a synchronized chopper system, which is currently being installed;
- Modulate the probe beam with a faraday rotator in a double modulation configuration (both beams are modulated, the probe for instance with the rotator and the pump with the chopper).

3. Main Results

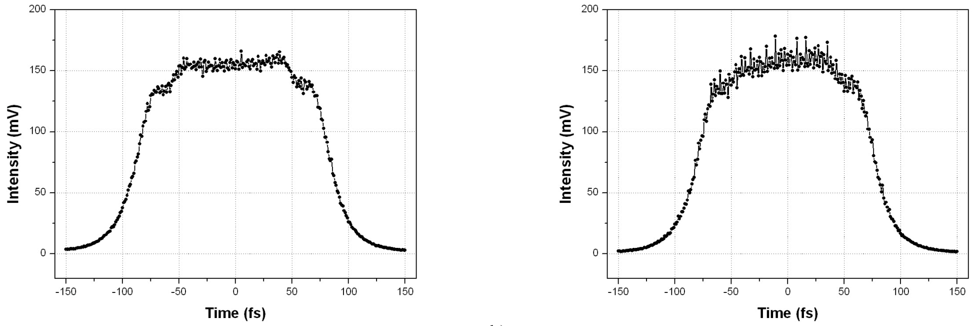
3.1 Week 1

Here we present the results of the autocorrelation signal of the two beams, generated by the nonlinear process of second-harmonic generation (SHG). After I found the temporal overlap of the beams, I started to measure the autocorrelation signal of the SHG of the two beams. I tried to improve the pulse by varying the dispersion, moving a prism of the laser system, and the width of the slit that allows this laser system mode-locking. In all the results is observed signal saturation thus it is not possible to evaluate the pulse width.



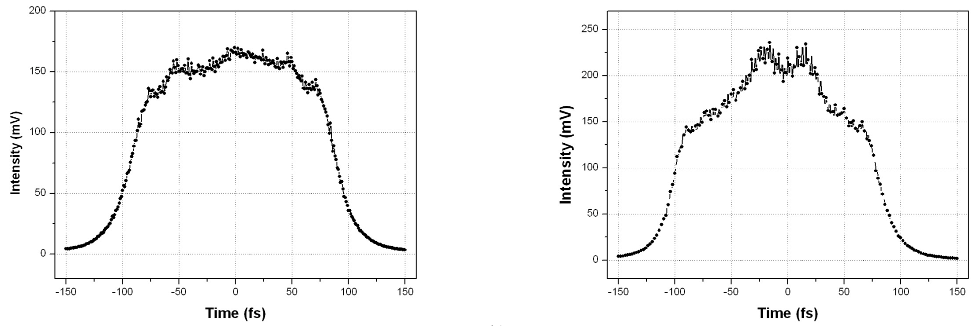
a) b)

Fig. 3. Autocorrelation signal of the SHG of the two beams: a) first measurement with a large step scan after; b) same conditions used at a) with a smaller step scan.



a) b)

Fig. 4. Autocorrelation signal of the SHG of the two beams: a) the dispersion was changed but the signal is almost equal to Fig. 3.1.1 b); b) the dispersion was adjusted again as well as the slit width.



a) b)

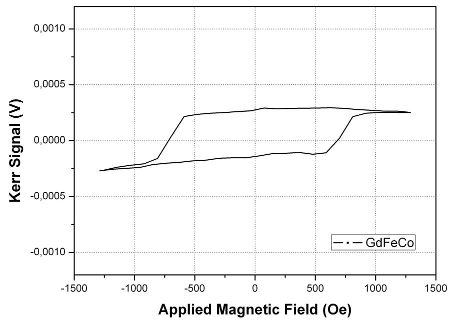
Fig. 5. Autocorrelation signal of the SHG of the two beams: a) the pump laser power was change from 8.5W to 9.5W; b) here the pump laser power was 10W.

3.2 Week 2

We recorded hysteresis loops for GdFeCo and FeCu thin films, as well as time-resolved MOKE (TR-MOKE) measurements to study their signal detection and acquisition system.

i) GdFeCo thin film

Hysteresis loops for the GdFeCo thin film without pump. This sample has a strong MOKE signal, so it is ideal to start the study. The applied magnetic field configuration used: the field direction is in-plane with the sample surface and perpendicular to the incidence plane (MOKE-longitudinal configuration).



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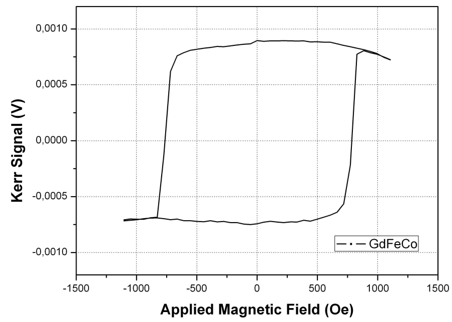
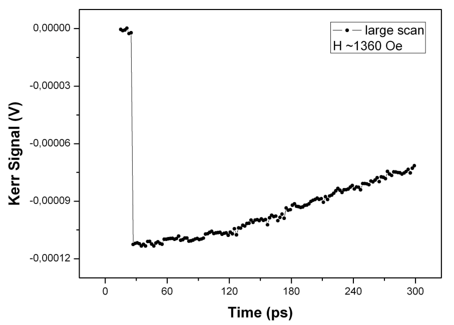


b)

Fig. 6. Hysteresis loops without the pump pulse for a GdFeCo thin film: a) loop before optimize the signal; b) loop after optimize the signal.

We now present the TR-MOKE measurements for the GdFeCo thin film. First we recorded a larger scan to find the temporal overlap between the probe and pump beam, then a short scan in the overlap region with smaller steps to have greater temporal resolution. Another scan was recorded with the pump beam less attenuated (we removed some of the neutral filters) to change the fluence, however the sample was damaged by an excessively intense pump beam.



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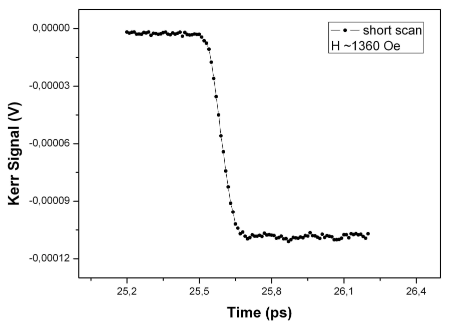

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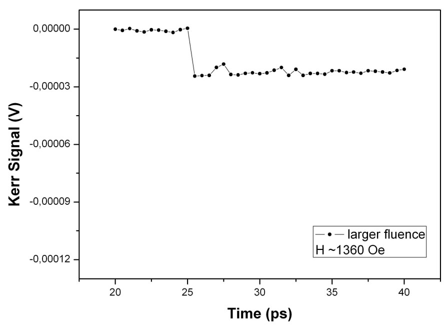


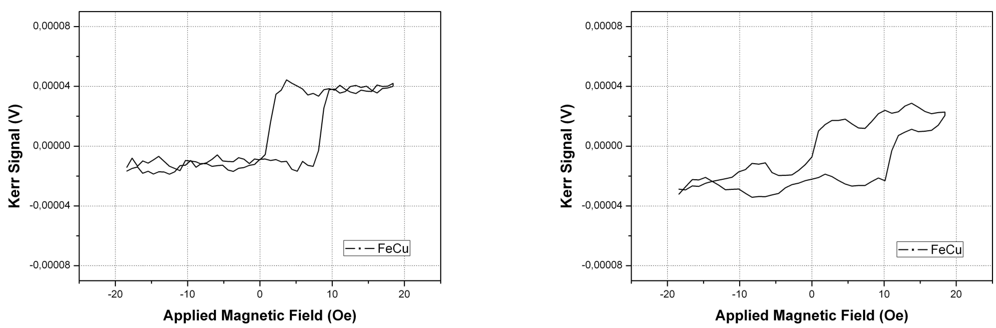
c)

Fig. 7. TR-MOKE measurements for the GdFeCo thin film: a) larger scan to find the temporal overlap; b) shorter scan to get a better resolution in the overlap region; c) scan with a different pump fluence, the sample got damaged.

ii) FeCu thin film

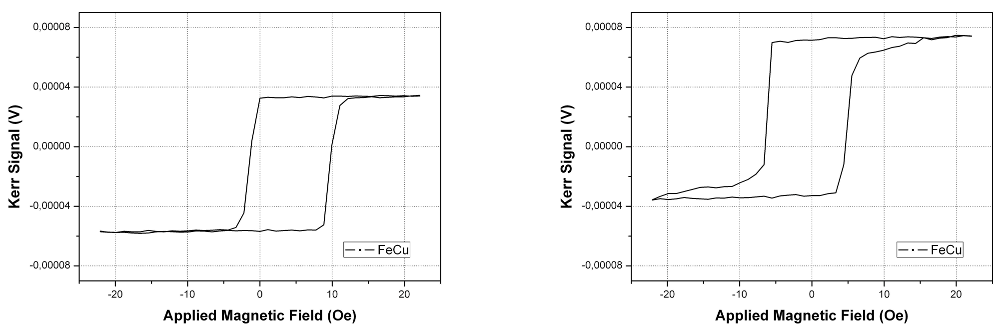
Hysteresis loops for the FeCu thin film without pump. For this sample we used two different configurations. The first configuration: the same as was used with the GdFeCo sample, as indicated above. The second configuration: the applied magnetic field direction makes a ~45º angle with the sample surface and the incident angle of the probe beam is also ~45º.

The loops are not centred in the vertical and horizontal axes. In the vertical axis, this was due to the fact the signal was not well balanced. In the case of the horizontal axis, the cause of the problem was the sample position, which was closer to one of the magnet poles than the other. In the Fig.2.3.3.4.b) we see the hysteresis loop is not completed saturated this is due to the fact that the sample region probed was already damaged.



a) b)

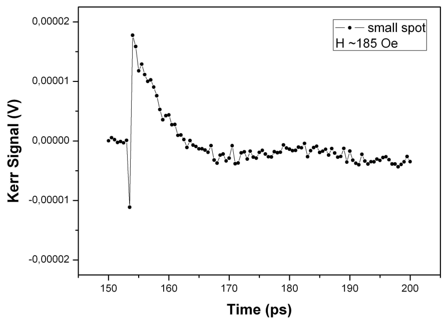
Fig. 8. Hysteresis loops without the pump pulse for a FeCu thin film: a) loop recorded in the 1st configuration; b) loop recorded in the 2nd configuration before optimize the signal.



a) b)

Fig. 9. Hysteresis loops without the pump pulse for a FeCu thin film: a) recorded result in the 2nd configuration after optimize the signal, 8 loops averaged; b) recorded result in the 2nd configuration after optimize again the signal in other region of the sample, 8 loops averaged

The TR-MOKE measurements for the FeCu thin film were recorded in the second configuration. We take larger scans to find the temporal overlap between the probe and pump beam. The overlap region we found is was different since when we change the configuration also changes the beams path lengths. We also recorded scans to study the effect of the pump fluence. Changes in the pump fluence on the sample were obtained by moving the pump lens to change the pump spot.



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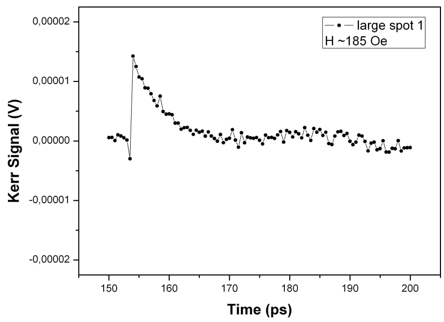

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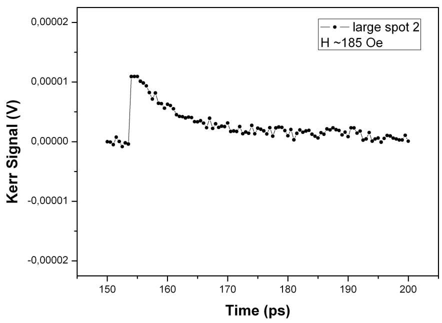

c)

Fig. 10. TR-MOKE measurements for the FeCu thin film: a) scan with a small spot (larger fluence); b) scan with a large spot; c) scan with a even larger spot.

4. Future Collaboration

We have recently concluded the first phase of the establishment of an ultrafast setup for the measurement of magnetization dynamics. After this first phase we made several improvements that allow us to commence our time-resolved MOKE measurements and initiate research into ultrafast magnetization processes provoked by femtosecond laser pulses.

Since our system has been developed, it is now possible to exchange researchers with the laboratory of Prof. Theo Rasing and Dr Alexey Kimel to allow knowledge transfer and initiate some studies in ferromagnetic systems using our unique laser source.

We have a unique source in that we have state-of-the-art capabilities for pulse compression, which can produce pulse widths of the order of 5 fs at the sample. This pulse width is significantly shorter than other laboratories working in the area and will allow us to be competitive in our research aims. It will also provide a point of interest with the Nijmege laboratory, which has an impressive track-record in the area. This, it is hoped, will enable us to perform cutting edge research into the study of the mechanisms of ultrafast demagnetization and fundamental magnetic processes in a range of materials and structures.