
Sherbrooke Street on the southern end of the McGill campus.

Master Thesis Project at McGill University

"Femtosecond Time Resolution in FM-AFM by Incorporation of a Ultrafast Pulsed Laser System"

For my Master's Thesis, I had arranged a project with the research group of Prof. Peter Grütter at McGill University, Montreal. I'd been made aware of Prof. Grütter's strides in the field of SPM from multiple sides, and had a chance to visit a talk given by him at our own institute. Thus, the link was formed and subsequently a project was established.
In the middle of January 2017, I flew to Montreal for 6 months.
The focus of my project involved modifying an existing laser setup which was fed into an air-damped UHV-AFM system. By using two pulsed lasers which had their pulses delayed in respect to each other, the group had succeeded in conducting pump-probe measurements, essentially two pulses generating a cantilever response in rapid succession. The key in this measurement is the fact that the overall response is dependent on the potential overlap of the individual pulse responses, opening up the possibility of observing fast decay times with a comparably slow oscillator, or cantilever. This phenomenon is owed to the nonlinear nature of the signal decay.

My part in this setup consisted in modifying the laser system to utilize only one source beam, allowing for shorter overall pulses and a stable delay.
To allow the determination of the zero-delay setting in this new setup, I needed to incorporate an optical intensity autocorrelator into the laser system.
Lastly, the main objective of my Master's Thesis consisted in proving that the time resolution limit of this pump-probe approach is only limited by the pulse width of the pump-probe laser. To do this, I made use of a nonlinear crystal, Lithium Niobate, and an innate effect called optical rectification, which generates strong electric fields only when irradiated with suitably polarized light, i.e. our laser system.

Using this approach, we were able to observe an interferometric pattern in the measurement, leading to the conclusion that this particular setup functioned as an interferometric autocorrelator, and alongside proving that our AFM system could resolve delays of up to 31.3 attoseconds using this approach. In my opinion, this Master Thesis Project has been a resounding success.

This success was a welcome relief, as the project initially suffered delays due to system malfunctions and an overlap with a visiting reasearcher, which effectively delayed the beginning of the practical part by 10 weeks. Once the laser system could be modified, it took roughly 5 weeks to build and optimize the autocorrelator, which was partly due to the fact that I myself had little grasp of the technical details. Additionally, more specialized components were needed and were provided after the 4th week by a collaborating Professor for Optics, which jumpstarted the process and allowed the successful construction of the autocorrelator. Subsequently, sample preparation with the Lithium Niobate proved a bit tricky, but less time-consuming.
Lastly, the measurements went very well and the results are currently in the process of being prepared for publication.

I have personally made many formative experiences during this project, most of them related to independent working and the inner machinery of academia.
Furthermore I've had the priviledge of experiencing a vastly different culture and country, for which I am grateful .
I would like to annotate that the Grutter Group provided me with excellent supervision (also owed due to the fact that the system was worked by said supervisor and an additional student). In addition, the collaboration with an optics lab proved invaluable to the success of the project, providing key insights and components.
Also, as a bonus, including myself, our subgroup was composed of 75% swiss people! (My supervisor was Zeno Schumacher, a PhD student in the same lab was Andreas Spielhofer.)

Culturally, Montreal has diverse international cuisine, which is in addition very affordable, as opposed to what one may be used to in Switzerland. Boston and New York as well as Quebec City and Ottawa are short to long bus-rides away, and while I myself only ever found time to visit New York City (which I recommend), other destinations are certainly worth looking up in the summertime. Winter, on the other hand, revolves mostly around Hockey and you'll find that Canadians are very warm and inclusive people. I find myself looking back at times for the people I've met overseas, but on the other hand I have missed the swiss landscape tremendously (apart from the hill giving Montreal its name, the surrounding landscape is flat)!

I would like to thank the SNI for supporting me with the Argovia Travel Grant for this journey by helping to cover the costs for the flights and rent, and specifically our Dr. Spieler and Ms. Isenburg for providing tips and feedback for the application process.

Raphael Pachlatko, August 26th

A few pictures are appended to give a brief impression.

A blizzard which paralyzed the city mid-March (!) -It didn‘t stop us from going into the lab.

Easter Sunday 7 am in NYC, the Chrysler Building in the distance.

The skyline of Montreal as seen from Mont Royal, end of January this year.