TAYLOR VISION

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MEMS Thermal Actuator
Ion Pipette
Dimensional Optical Metrology
Taylor Agenda

TU Delft Delft University of Technology

Section Precision and Microsystems Engineering

February 2009

Dispuut Taylor - Mekelweg 2 - 2628 CD DELFT

Preface

Hi there PME-member!

Shall we not focus on the financial troubles in the world for a moment and focus on the fun things in our safe, academic world? Now that the students are finished with their exams it's time to kick start the Taylor activities!

Fist of, in this fully loaded Taylorvision we will look back on the activities of the last couple of months. In this edition of the Taylorvision you can find reports of our visit to the Precision fair, our Golf adventures and how we informed the Bachelor students about PME. Furthermore in this Vision:

- Sander Paalvast gives an insight in the development of a thermal actuator for hard disk drives.
- Friedjof Heuck introduces the ion pipette.
- Jonathan Ellis explains about dimensional optical metrology.

In the upcoming months the board will focus on the organization of the upcoming Taylortrip. As soon as we can, we will announce the companies and cities we will visit. Soon after that we will start inquiring who wants to join us! So keep checking the website and the announcement board for updates!

On behalf of the 2008/2009 board,

Wijnand Harmsen
Chairman Taylor

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Board
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Jan-Willem Bots

Erik Schutten

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PME News

The new department

Not more than a year ago, when the average bachelor student entered the faculty of 3mE, he bought himself a cup of coffee, turned left, stairs, right and then straight on until the humming sound of a hundred computers told him he arrived at his destination; the computer rooms. Since last summer however, not only the humming noise is gone, but also the hallway system has undergone a drastic change.

Although warned by Jan Neve’s 3D animation, the amount of yellow that people could fit in one room absolutely stunned everybody walking into the PME-wing for the first time. But as it always goes with new things, after a couple of weeks you will get acquainted with them and another few weeks later you won’t even remember that it used to be different. Luckily for us, the designers had foreseen this habituation. Every time you was about to forget, a new element was brought in. First the windows were partly blinded and some extra yellow flavours were added to the look through doors. Because only hearing the person on the other side of the hall did not satisfy enough, the next step was to block the sound a bit better. Getting used to these changes while enjoying a nice cup of coffee however was hardly possible while the coffee machines were banned to make room for the most gigantic wooden furniture that arose in the central hall. As the days turned into weeks, the furniture got some colour and slowly it became clear that the wooden planks soon would form the giant letters “3ME” and would not only house our fridge and water supply but also the coffee machines would find their new homes inside.

Just as you thought this was the summit, a new set of workers filled the PME floors, this time to place some extra lights. If not meant to reassure you that the main colour still was yellow, than sure they were placed to ad a bit extra futuristic touch to the surroundings. When finally the chairs, tables and flowers were placed it was time to officially declare the new pantry opened during the New Year’s drinks. During the ceremony Fred van Keulen held a speech and Dean Marco Waas declared the department as opened.

Since the whole moving and rebuilding adventure has finally come to an end, only one question stays unanswered: will we start to forget, or will we always remember that within the whole university there is no department where you can drink your coffee in an environment as futuristic as ours?

Prof. Fred van Keulen and Dean Marco Waas opening the new department

MEMS Thermal Actuator for Hard Disk Drives

Hard Disk Drives (HDD) are used for long-term digital storage like in computers and MP3-players. A growing number of these systems use flash memory to store their data, as most of you will know. In the smallest laptops and netbooks flash based HDDs, called Solid-State Drives (SSDs), are common practice. However, for applications that require large capacities (e.g. server, desktop computers), conventional HDD technology is still competitive, because SDD cost about 10 times more per GigaByte. To maintain this competitive advantage, the HDD industry is continuously looking for ways to increase the capacity without reducing the cost (or size). Introducing new technology, such as MEMS micro actuators, will help to reach this goal.

In HDDs, the data is magnetically stored on rotating disks (figure 1). The data is read and written with a head which floats just above the disk. The head is connected to the actuator arm by means of a suspension. With a voice coil motor the arm can be rotated to position and to keep the head above the center of the desired track during read and write operations.

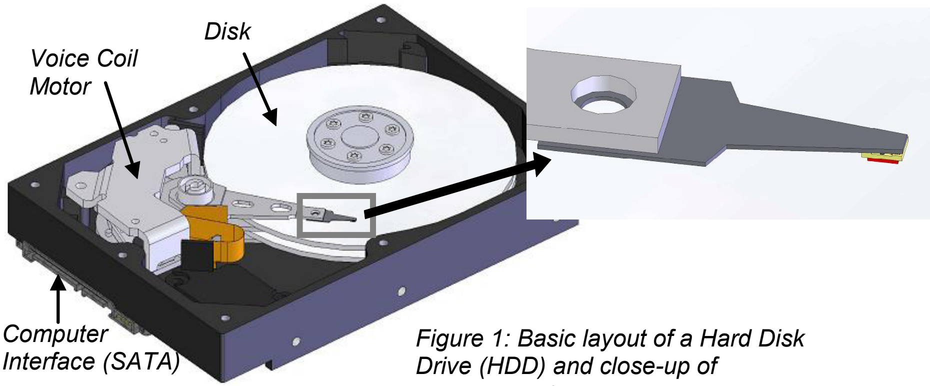


Figure 1: Basic layout of a Hard Disk Drive (HDD) and close-up of suspension & head.

To increase capacity, future drives will use narrower tracks, which requires a higher tracking accuracy. Increasing the tracking accuracy by increasing the servo bandwidth is limited by the destabilizing effect of a mechanical resonance in the actuator arm. This can be solved by using a dual-stage actuator, in which the positioning is split in a coarse- and a fine-stage.

The small fine-stage can have a relatively high bandwidth, improving accuracy and seek time. Also, the fine-stage can compensate for the small position errors due to the friction in the ball bearing of the coarse actuator arm.

MEMS fine stage actuator

The smaller the fine-stage actuator, the higher the bandwidth and the accuracy of the positioning system can be. Therefore different Micro Electro-Mechanical System (MEMS) fine-stage actuators have been developed. These actuators are generally based on electro-static actuation which is fast and has low power consumption, but generates only small forces and uses small air gaps & electrodes. In this project a thermal fine-stage actuator (figure 2) is being researched, which can generate larger forces and does not require small air gaps or electrodes.

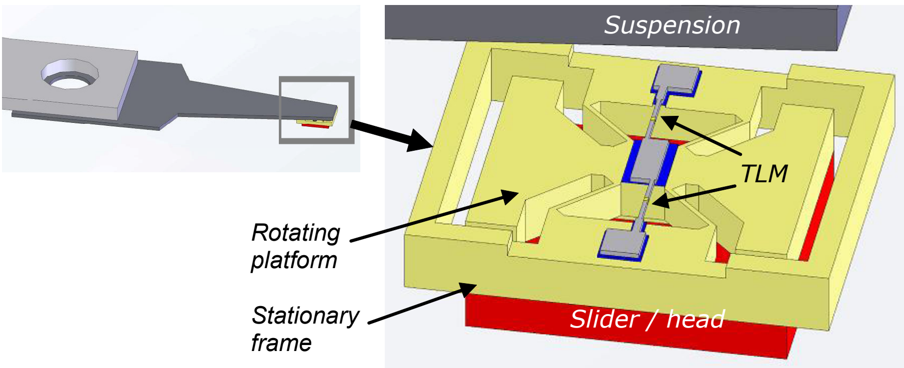


Figure 2:
The thermal HDD micro actuator is mounted between the suspension and the slider. The eccentric position of the two thermal linear motors (TLM) converts the small thermal expansion in rotation of the platform. These rotations translate into amplified displacement of the head, which is at the edge of the slider.

Thermal actuators are neither known for their high speed nor for their low power consumption, but when scaling down these disadvantages are reduced considerably.

Fast thermal actuation

The goal of the HDD micro actuator is to reach a positioning accuracy better than 5nm, and a servo bandwidth in the order of 3 to 5kHz. These performance requirements can only be reached if the actuator can be cooled down in less than 100microseconds (fast heating is a smaller challenge). To allow fast cooling the actuator must be designed to minimize the heat storage and maximize the heat conduction (i.e. heat loss) without compromising the stroke and force capabilities. This requires careful selection of the actuator materials and the material use (geometry).

In MEMS technology material selection is complicated by fabrication considerations. The equipment used for the fabrication of our actuators (at DIMES), are also used for making ICs. Contamination of the equipment can strongly affect the reliability of the ICs and must therefore be avoided. Aluminum is allowed in many machines and, luckily, aluminum also has good properties for thermal actuators, like high coefficient of thermal expansion, high thermal conductivity and a decent Young's modulus (force). That is why in our thermal HDD actuator, we use aluminum for the driving elements, the Thermal Linear Motors (TLMs).

In our original TLM (figure 3) the heaters are made of silicon because it has higher electrical resistance. This reduces the required actuation current but at least 10 times. Lower currents generate lower electric fields (less electrical interference) and less power is lost in lead wires, amplifiers, etc.

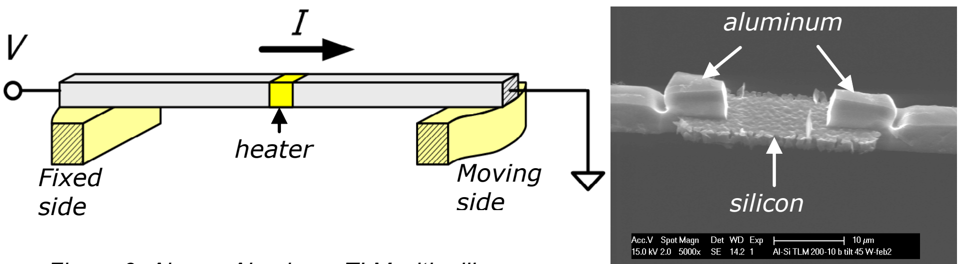


Figure 3: Above: Aluminum TLM with silicon heater for low current operation.
Right: SEM image of silicon heater.

Currently we are working on an improved, aluminum TLM, which has a high electrical resistance without using silicon. This simplifies the fabrication process considerably. A second bonus is the linear temperature versus resistance relation which is highly non-linear for silicon. This means that no calibration is necessary to determine the heater temperature from the resistance change. Also, initial tests have shown that the improved TLM is less sensitive to buckling.

Shape optimization of static or quasi-static thermal actuators improves the stroke versus power consumption by reducing the heat loss to the frame. In our case good heat transport to the frame is required for fast cooling. Another approach is therefore followed. Using finite element models and simulations we came up with a new TLM that uses about 20% less power without reduction in stroke, force or dynamic response.

Micro Mechatronics

Fabrication challenges are a big aspect of any micro-actuator research project, including this one. However a fine-stage actuator optimized for (easy) fabricated is most likely not a good actuator from performance point of view. The thermal actuator is not a stand-alone system, but a part of a precision mechatronic system and must be designed as such.

The micro-actuator must work together with the coarse actuator instead of interfering with it or vice-versa. This means that the thermal actuator is not allowed to excite the resonances of the coarse actuator arm, and it should be able to handle the large accelerations of the voice coil motor. The actuator must be designed for good controllability, which dictates reproducible behavior (preferably also linear) and low thermal time constant. Many other, often contradicting, requirements must be taken into account which makes this project an interesting case-study for Mechatronic System Design in the micro domain.

My project is a collaboration between PME-MSD and the DIMES Electronic Components, Technology and Materials (ECTM) group, and is funded by the STW.

Sander Paalvast (PME-MSD)

Ion pipette

Hi, I am Friedjof Heuck and I am part of new the Micro and Nano Engineering laboratory. Maybe you're wondering about the new cubicle in Hall 5A and especially that weird guy inside all day long staring into a microscope. Well that's me and my tiny Micro Electro Mechanical Systems (MEMS). Our group's focus within the department Precision and Microsystems Engineering is in the area of Microsystems. In my view, MEMS is a perfect path for the development of mechanical engineering. It combines the classical ideas of mechanics with new fabrication technologies deduced from the semiconductor industry to get micro-scaled smart systems. These systems demonstrate the interaction between actuators, sensors and control. The scope of MEMS devices is extremely diverse starting with chemistry, electronics and optics just to mention a few.

My PhD topic is the scanning ion pipette (SIP). Scanning originates from scanning probe microscopy. This microscopy technique can be visualized by a blind man's walking. He constantly probes the surrounding surface by scanning it with the tip of a stick. In the case of SIP, the "stick" is a 150 μm long freestanding cantilever (Fig. 1a) with a very sharp tip, the radius of which is in the range of 100 nm (Fig. 1b). Putting this together allows you taking nice images such as the measured tracks from a CD shown in Fig. 1c. So much for "scanning".

The "ion pipette" part needs a bit more of an introduction. The main focus of the SIP is for micro-scaled fluid handling on a single chip. Therefore we need first of all small capillaries. In this case the inner dimensions of the capillary are 2 μm × 3 μm surrounded by a 1 μm thick sidewall (Fig. 1d). Just for a physical size scale, the capillary is roughly 20 times smaller than the width of your hair.

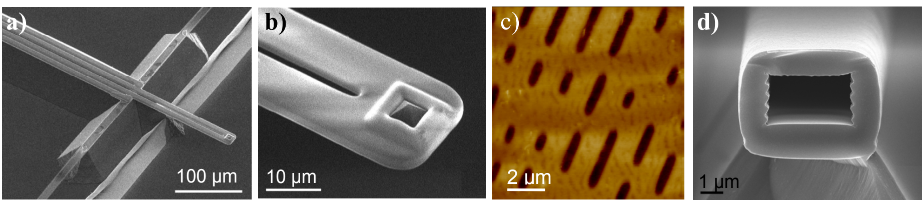


Fig.1. Scanning electron image of a) a freestanding cantilever, b) tip of the SIP, c) SIP image of CD tracks and d) Scanning electron image of the capillaries cross section.

On chip pumps are needed for conveniently handling the fluids. The pumps used in the SIP are so called electro osmotic pumps. These pumps take advantage of the fact that the surface forces become more dominant compared to the volume forces when feature size is shrinking. The general idea is as follows: (i) we have a capillary sidewall, which is electrically insulating and charged. Simple glass surfaces fulfill this requirement. (ii) Our liquid within the capillary needs to compensate this surface charge with mobile charge carriers. Water filled into the capillary compensates the surface charge with its dissolved ions. Therefore mobile ions accumulate at the capillary sidewall. (iii) The last step is to apply an electric field along the capillary that drags these accumulated ions and hence pumps the liquid. The challenge is to establish two independent electrodes, one at the beginning and one at the end of our pump. An example of an electro osmotic pump is shown in Fig. 2a. Additional to the pumping electrodes can also help us obtaining information about the dissolved ions and their concentration.

How do we fabricate this tiny fragile and complex system? MEMS fabrication gives us a useful tool. Don't worry; I won't go into too many details, but let's say that the MEMS fabrication is significantly different than the classical machining of drilling, milling and cutting. A major difference is parallel processing. Could you imagine fabricating all the transistors in your CPU one by one? – See, parallel processing is essential!

I will introduce only the three main workhorses of MEMS technology: Layer creation, Lithography and Etching. First we create a layer by deposition or transformation on the surface of our work piece. Layer thicknesses normally range from a few nanometers up to a couple of micrometers. For the Lithography we spin a thin layer of a photosensitive material onto our freshly created layer. By partially exposing the photosensitive material we induce a difference in solubility between the exposed and non exposed parts. Dissolving one part leaves the desired pattern behind. A standard rule here at DIMES is count for a smallest feature size of 0.5 µm. The IC industry especially Intel is trying to push this limit to amazingly 32 nm. The final step is the pattern transfer into the layer for which we need etching. The two main parameters we can play with are the selectivity, which is individual etch rates of different materials, and the anisotropy, which is the directional dependence of the etch rate. By different combinations and repetition of these three steps we create the SIP.

However, I still didn’t answer the most pressing question. Why and where do we need the SIP anyways?

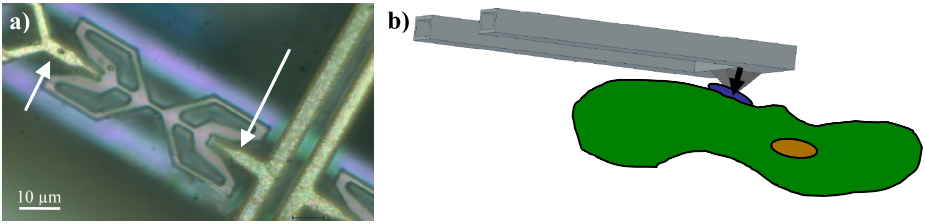


Fig2. a) Optical microscope image of electro osmotic pump. The independent electrodes are represented by the grainy and reflective parts indicated by arrows on the left and the right of the transparent electro osmotic pump. b) Sketch of the SIP dispensing bioactive molecules on a cell membrane.

The SIP should enable us to extend the high resolution imaging capabilities of a scanning force microscope with locally precise dispensing and sensing of liquids. Our first target is in cell biology, it is of high interest how substances enter or exit a cell through the membrane. There are plenty of so called gating proteins in the membrane, which are actively controlled by bioactive molecules. Here the SIP comes into action, by dispensing a specific bioactive solution in the close vicinity of the gating protein we aim to induce a structural change of the gating protein like opening or closing a valve. At the same time we monitor this motion (Fig. 2b).

Friedjof Heuck

Dimensional Optical Metrology

Hello, I am Jon Ellis of the Mechatronic System Design group in the PME department. One of the research topics within the MSD group is dimensional optical metrology, which is a fancy way to say “using lasers to measure length very accurately”. Currently, we have two main research projects running on linear displacement interferometry and material stability interferometry.

Dr. Ki-Nam Joo, a postdoc, is the main researcher for the linear displacement measuring interferometry (DMI) project. He is focused on enhancing and developing DMI techniques for industrial applications. This includes improving measurement resolution, nulling air turbulence effects, and removing periodic nonlinearity. This is of interest to hightech companies that require precise measurements at high sampling rates, such as in lithography tools, fast tool servos, and space applications.

The other project on measuring material stability is the main focus of this article. This is my main research for my PhD dissertation. In the world of designing precision systems such as lithography machines, satellite telescopes, diamond turning machines, etc., one of the most crucial aspects in the design is the effect of thermal fluctuations. To counteract this, many systems have been developed or are being developed with extreme environmental control. This is typically on the order of 10 mK temperature fluctuations with either no air flow or a controlled air shower. By utilizing strict temperature controlled environments, the thermally-induced dimensional changes of components in the system are minimized.

Because the thermal envelope is so tightly controlled, the subsequent expansion seen in instruments is a combination of thermal and “other” motion. Those “other” motions are typically described as drift. What we are doing in this research is building an instrument to measure those drift motions. By measuring the drift motions, you can investigate potential sources of drift and once understood, you can hopefully design around it.

That is the overall goal for this project. Now when we talk about drift, the motions are very small. The instrument we’re trying to build has the following target specifications: 1 pm (picometer, 10-12 m) resolution, 10 pm of uncertainty for 1 hour measurements, and 100 pm uncertainty for 4 weeks of measurements.

The reason we say "uncertainty" is because this value needs to be traceable to national and international standards. This means there are a set, agreed-upon, criteria and specifications for how you claim how good your measurement is. Ultimately, this means that while your digital readout may have 20 digits, you're not really getting 20 digits of "accuracy". Ok, just so I don't bore you to death with text, I'll start the pretty picture section. To do these measurements, you need an interferometer, which is shown in Figure 1. In this figure, 2 slightly different laser beams are directed into the system. The gray dashed beam measure the sample and interferes with the solid gray reference beam. The black dashed beam measures a vacuum tube (VT) and interferes with the solid black beam. Measuring the vacuum tube helps you to get rid of the air-induced errors. By comparing the phase difference between the signal from Pdr and Pds (Fig. 1), you can determine how much the sample length is changing.

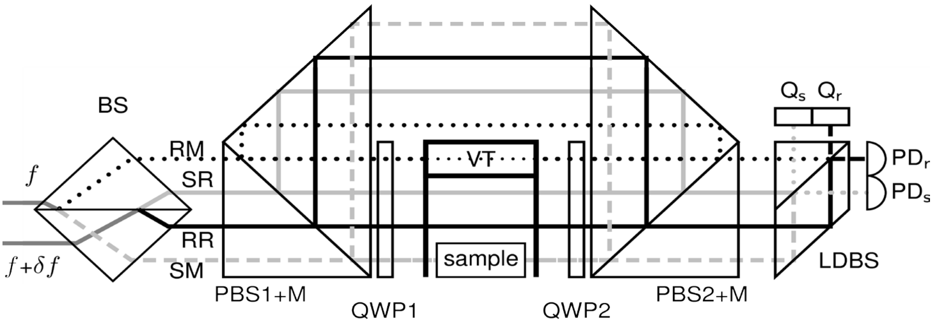


Figure 1: Schematic of the interferometer layout for measuring sample drift. This is a dual interferometer which measures the sample and the air fluctuations, reducing the effects from air turbulence

To give you a feeling for what this would look like in real life, I've conveniently added a picture in Figure 2. Now, while the schematic shows the interferometer left-to-right, on the breadboard, it's actually right-to-left. Basically, we use some fiber optics to launch the beam into the system, then use some big optics to split the beams and chase them around the interferometer, only to then recombine them on two commercial detectors. By measuring the phase difference on the detectors, you can determine the length change.

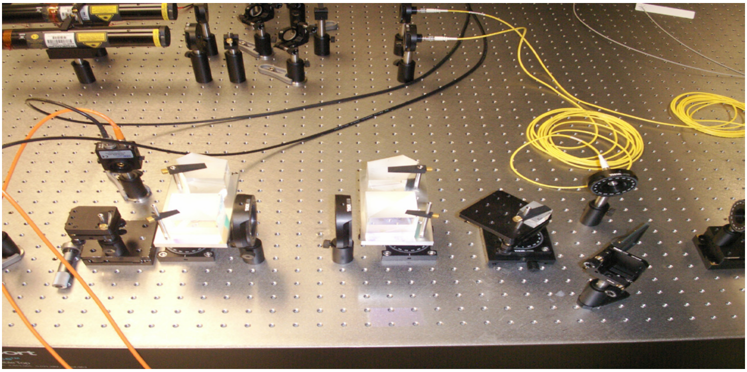


Figure 2: Picture of the test setup in the clean room

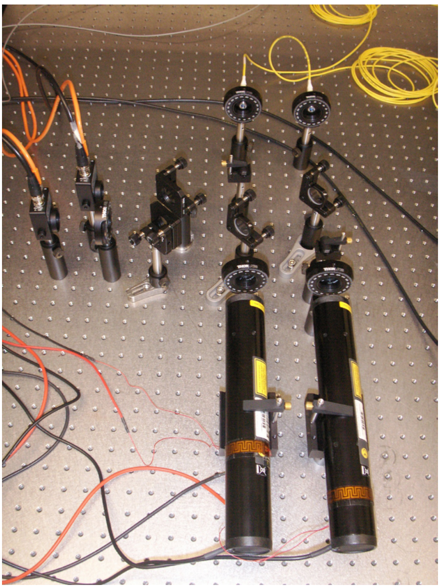


Figure 3: Offset locked laser system. (MS STUDENT WANTED!!)

Now, both my interferometer and Ki-Nam's interferometer both use a novel, offset-lock locked source, which is shown in Figure 3. This is where there are some opportunities for additional projects. We're looking for some master students to work with us in this area, which is laser locking and electronics.
If you're not interested in that, don't worry, we've got other projects on data acquisition and FPGA programming, Fabry-Perot interferometry, and 6 DOF optical sensors. If you're reading this article and you say to yourself "Hey, this looks interesting. I want to learn more" then send me an email (j.d.ellis@tudelft.nl), call me (x89503), or just look for the really loud american. Oh, if you found yourself an american, and he's quiet, then that's probably Eric, not me.

Jon Ellis

Foreign internship: CRCMining – Australia

At the beginning of July 2008 I took an airplane with the destination Sydney, Australia. Two months later I started my internship at CRCMining at the University of Queensland after an exciting roadtrip through Australia.

First some background about the company I worked for: CRCMining is a multi-million dollar research centre found in 2003, and established by the Australian Government under the Cooperative Research Center program. The centre is supported by four universities and fourteen industry partners. As you would suspect from the name the main expertise of the research centre is mining technology. Mining is a primary industry in Australia and a significant contributor to the Australian economy. High labor costs, first-world safety regulations, and distinctive geology forced the mining sector to become an advanced industry.

All this sounded interesting enough to me to fly all the way down to the other end of the world. Of course there were also some other reasons that helped me making this decision, but now first some words about work. The department I worked for, called the smart machines group, is located at the University of Queensland in Brisbane. The latest work the group is concentrating on is automation of electric mining shovels. The main considerations for automation are optimization of the mining process and safety; the harsh working environment, dust clouds or heavy showers, make it often impossible for the operator to get a clear view of his surroundings.

Automation of a large mining shovel requires knowledge of the digging environment. This information is acquired with a combination of multiple axes scanning lasers, radar, and GPS. Of high importance is also detailed information of the shovel's configuration in order to avoid collisions with the digging face and waiting haul trucks. And of course one needs to understand the dynamics of the excavator fully in order to control the shovel.

During my internship I worked on different projects, which varied from a sensitivity analysis for a range sensing laser to building a controller for the swing movement of the shovel. Interesting was that our department has its own electric mining shovel in a nearby quarry, so if needed you could go there to test your work on the real machine.

Next to work there are a lot of different things to do in Australia. I thought three months would be enough to explore the country, but that turned out to be underestimated. But nevertheless it was enough to get a good impression of the country. With a friend I bought a big Ford Falcon with an oversized 6 cylinder (4 liter) engine to cruise around. During our roadtrip we quickly adapted to the Australian habits of having good barbeques and drinking beer. I can recommend especially the kangaroo steak (medium rare). Our car brought us from Sydney al the way along the fairly touristic east-coast up to Cairns where we drove through the red centre down again to Adelaide. From there we took the Great-Ocean road to Melbourne and finally succeeded back to Sydney.

In Brisbane I experienced the advantages of working on a university and living in a student house; making new friends was easy, and I never got bored during the evenings or weekends.

At the moment I'm back acclimating to the Dutch weather and culture, and looking back to an experience I won't forget quickly.

Have a good one, cheers!

Meindert Solkesz


HEIDENHAIN
Hoeveel miljoen functies passen er morgen op een microprocessor?
Waar functionaliteit en kosten tellen, mag geen plekje onbenut blijven. Dat geldt ook voor wafers. Steeds kleinere structuren op steeds grotere formaten: Deze schijnbare paradoxale eisen zorgen voor een optimaal gebruik. De eisen die gesteld worden aan lengte- en hoekmeetsystemen luiden daarom als volgt: De hoogste nauwkeurigheid en de kleinste resoluties bij steeds grotere meetbereiken. Een voorwaarde waaraan voldaan wordt door de meettechniek van HEIDENHAIN, want door voortdurend onderzoek en permanente ontwikkeling zijn wij vandaag al gereed om de schijnbare tegenstellingen van morgen op te lossen. HEIDENHAIN NEDERLAND B.V., Postbus 92, 6710 BB Ede, Tel.: (0318) 581800, Fax: (0318) 581870, www.heidenhain.nl, E-Mail: verkoop@heidenhain.nl
Hoekmeetsystemen + Lengtemeetsystemen + Contourbesturingen + Digitale uitlezingen + Meettasters + Impulsgevers

Visit to Precision Fair

The annual Precision fair took place on the 26th and 27th of November in Veldhoven. On this fair more then 200 companies presented themselves and therefore it was an ideal place to meet with people from companies active in the precision and micro field and get ideas for internships and graduation projects.

Our visit was planned on Thursday the 27th. We left the faculty with a group consisting of Master students and PhD's, all hoping to meet interesting companies. We arrived around 11.30 and after a refreshing cup of coffee we started to explore the fair.

It didn't take long before we started to see some familiar faces: the representatives at the stands of Heidenhain, Demcon and IOP greeted us with great enthusiasm as always. Unfortunately, there was no time for magic Heidenhain tricks, better luck next time! It was good to see a lot of interested people at the stand of 3TU where PHD's of PME presented their research projects. It looked like there was some serious networking taking place!

After catching up with old friends it was time to meet some new interesting companies. The Taylor board had a special agenda of course: meeting companies for future excursions and ideas for the Taylor Trip… and so the collecting of business cards began! We met up with a great variety of companies in the fields of mechatronics, production technology and high tech mechanics. The majority of them responded positively when we asked if they wanted to be more involved with master students. Besides that there were some constructive talks about company visits for later this year, so keep checking your mailbox and the announcement board!

Resting at the fair

After a long afternoon of pillaging the fair it was time to make up the score will enjoying a nice free drink. Besides a large amount of business cards we collected some chocolate, more flyers then we could carry, cool gadgets, many pens and even some scarves!

Before we would take the long ride home back to Delft, we had a nice meal and some drinks in the city center of Eindhoven. After a day like that, we had enough to talk about!

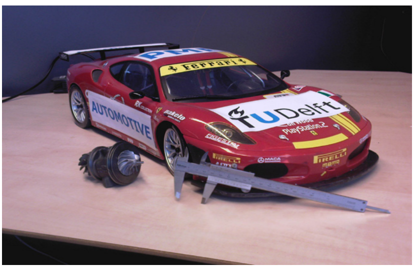
The Taylor board

Promoting PME to Bachelor Students

In the week of Monday November 17th the faculty organized several activities to inform Bachelor students about all the Master programs that are available at 3ME. The program consisted of a general info market on Monday and an activity which focused solely on one Master. The students who chose the come and explore PME were treated to an interesting tour through the laboratories of our department.

As said on Monday the interested students could come and meet all the Master programs in 3ME. Each Master had set up an interesting stand build up from graduation posters, interesting test set-ups and cool gadgets. For our stand we got help from all lot of the professors and PhD's who provided interesting objects and video footage of their research. This was very useful because nothing explains topology optimization better than a movie clip and an up scaled model of a MEMS device shows its complexity very clearly. Besides these gadgets and multimedia, the people from the MEMS practical supplied the stand with a working example of a thermal micro actuator which could be watched under a microscope. A lot of the people who visited our stand had never seen a MEMS structure before and were surprised by its capabilities. But the true hit at our stand was our RC Ferrari decorated specially for this occasion with automotive sponsoring!

Besides the market, each Master held two presentations about their departments. For PME Prof. Munnig Schmidt and Prof. Staufer explained the curriculum to the listeners and gave examples of the ongoing research in the department.



The Taylor Ferrari in all its pride!!

On Tuesday a tour through the laboratories was organized for students who wanted a closer look. The tour gave a good perspective on the facilities and activities in the department. Stops on the tour included the Micro Factory lab, the physics lab, the automotive test bench, the dynamics lab and the new clean rooms. In between stops the students were also treated to a presentation about the difficulty in designing and producing Microsystems. Although the size of the group was modest, those who attended appeared to be interested and maybe even a bit overwhelmed with the amount of information and the diversity within our group.

After the tour, a lunch was organized at the pantry. Whilst enjoying a sandwich PhD student Hans van Gurp presented his Master thesis and thus gave a clear example of the possibilities for a graduation project. Besides this presentation the attending students could ask their questions to some veteran PME students in a casual conversation.

After these two days of PME promo-ing the questions remains how effective they were. Clearly the department would like to welcome more new faces next year and thus it may be advisable to organize another promotional activity before the summer vacation starts.

Finally, we would like to thank everybody who invested time and effort into the organization of the activities on November 17th and 18th and for providing material for our market stand. It is highly appreciated.

The Taylor Board.

PME Golf

On the 10th of November a select group of PME students gathered at the Taylor Office for an extreme sports experience: Pitch and Put golf! For the ones not familiar with the Pitch and Put variant, I'll give a short introduction: Where golf is usually known as a somewhat elitist sport, where you need a so called "GVB" (a Golf permit) to even be allowed to enter the golf course; Pitch and Put golf is the opposite. Pitch and Put can be seen as golf for "the people", it only involves two clubs (one could thus make a comparison to the Sovjet Union, which was also based on only two tools: the Hammer and Sickle) and the distance to the holes is around 70 meters.

A brief introduction to the noble game

When all fifteen participants where present, route maps where distributed among the co-drivers and soon a total of four cars left the parking lot at the Leeghwaterstraat . After a short drive to Leidschendam (some of the cars took a slight detour, thus making it a long drive) and a drink in the club house (where some needed a beer to compensate for their bias error), groups where formed and the clubs plus golf balls where handed out.

After a short visual inspection of the golf/mud course I soon concluded rubber boots would have been more suitable than the leather shoes I was wearing. We got a short introduction on the rules of the game and some advice on a correct swing. After this short introduction the groups divided themselves over the golf course. While walking towards our starting holes, Jan Willem got a bottle of "Olifant" Dutch gin and plastic cups from his backpack and drinks were issued to keep us warm on the cold golf course. Sjoerd, Richard and I started at hole 11 and soon progressed over the course. Some of the swings went quite well, but still quite a few balls had to be "fished" out of the water. After about 2 hours, most of the teams finished the entire course and the scores were added. During a short "ceremony" in the club house the scores where announced and the team of Jan Willem, Rein and Lukas eventually won with a score of par +5.

Last year's chairman in action

From all the activity most of the participants burned a descent amount of calories, which all had to be replenished by a number of snacks, so the deep fryer had to do some overtime. After everybody was satisfied, we returned to Delft.

In the evening there were drinks in Café "de Ruif", here the beers and heroic tales were shared among each other, ending another great Taylor activity.

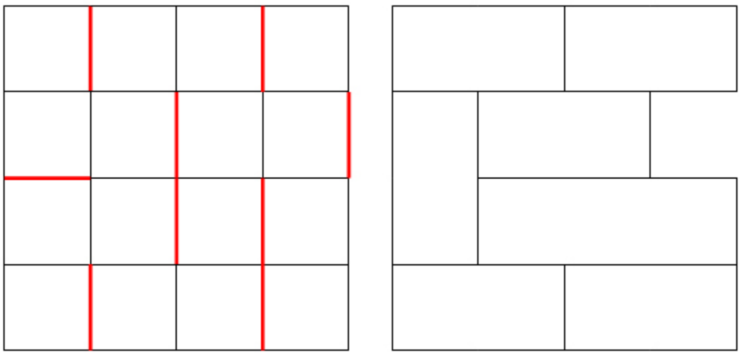
All and all it was a really nice day with a great atmosphere. So on be halve of all the participants, I'd like to thank the Taylor boys for a great afternoon/evening.

Paul van der Valk

Erik's Headbangers

Last issue's 'Meindert's Mindbreakers' was the last of its kind, but don't worry from now on you can test your intelligence with 'Erik's Headbangers'!

The solution to the matchstick problem of the previous issue is:



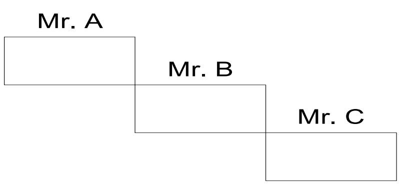
Congratulation to Matt Williams and Sjoerd Hesdahl for they were the ones that went home with a bottle of wine!

This issue I present you the following riddle:

'The wizard and the three men'

There was this wizard who caught 3 men {let's just say Mr.A, B and C}. The wizard wanted to kill all three of them, but they pleaded and so the wizard gave them a chance.

The wizard put the 3 men on flight of stairs, A first {A is on top of the flight of stairs} followed by B {B is in the middle}, and then C {C is at the base}, in this order:



They were stationed in such a way that A can see B and C, and B can only see C, but can't see A, and C can see none.
They were then blindfolded, and on each of their head, he put a colored cap, the color of the cap can only either be black or white, however, there will be either 2 black 1 white, or 2 white and 1 black, either way the 3 men don't know, all that they know is that there will be either black or white cap on their head, and that there will be either 2 white or 2 black cap on the 3 of them, which one they don't know.

So the wizard wants them to tell him what colored hat is on their head within the next 5 seconds after he removed the blindfold. Any one who could answer correctly would save the life of all 3 men.

Then, the wizard removed the blindfold……
After 4 seconds, the one in the middle {B} answer the question, and it was correct, how did he do it?

Hint: Whatever the answer is doesn't matter, even if it is white or black, the most important thing is how he got the answer.

Do you know the answer? Mail it to: DispuutTaylor@3me.tudelft.nl, the first two correct answers win a prize!

Taylor’s agenda

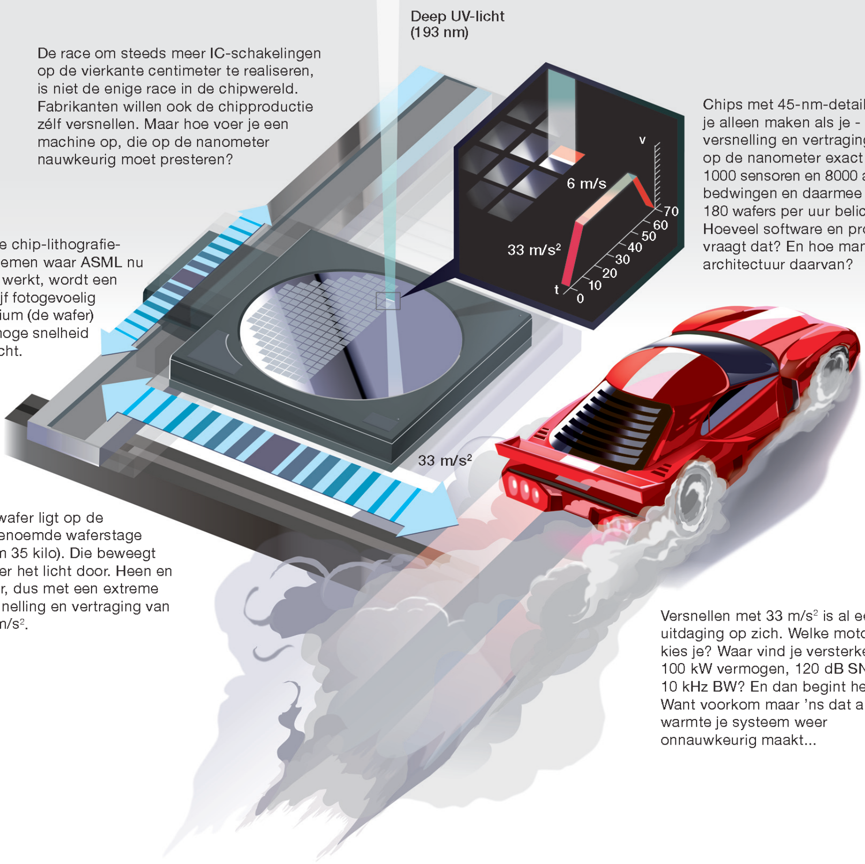
Here is an overview of our upcoming activities! Keep these dates free and keep checking the website for updates and information!

- **20 March: Visit to Heidenhain and to other companies**
- **6 April: PME Meeting April**
- **9-17 May: TaylorTrip to France!**

Don’t forget to check our website
www.taylor.3me.tudelft.nl
for the agenda and more information
about our activities!

Morgen kunnen we sneller chips maken. Vandaag mag jij ons vertellen hoe.

De race om steeds meer IC-schakelingen op de vierkante centimeter te realiseren, is niet de enige race in de chipwereld. Fabrikanten willen ook de chipproductie zélf versnellen. Maar hoe voer je een machine op, die op de nanometer nauwkeurig moet presteren?



Chips met 45-nm-details kun je alleen maken als je - tussen versnelling en vertraging door - op de nanometer exact belicht. 1000 sensoren en 8000 actuatoren bedwingen en daarmee 180 wafers per uur belichten. Hoeveel software en processoren vraagt dat? En hoe manage je de architectuur daarvan?

In de chip-lithografie-systemen waar ASML nu aan werkt, wordt een schijf fotogevoelig silicium (de wafer) op hoge snelheid belicht.

De wafer ligt op de zogenoemde waferstage (ruim 35 kilo). Die beweegt onder het licht door. Heen en weer, dus met een extreme versnelling en vertraging van 33 m/s^2.

Versnellen met 33 m/s^2 is al een uitdaging op zich. Welke motoren kies je? Waar vind je versterkers met 100 kW vermogen, 120 dB SNR en 10 kHz BW? En dan begint het pas. Want voorkom maar ’ns dat al die warmte je systeem weer onnauwkeurig maakt...

Voor engineers die vooruitdenken

Profiel: Wereldwijd marktleider in chip-lithografiesystemen | Marktaandeel: 65% | R&D-budget: 500 miljoen euro | Kansen voor: Fysici, Chemici, Software Engineers, Elektrotechnici, Mechatronici en Werktuigbouwkundigen | Ontdek: ASML.com/careers

ASML