Nanotools MicroFabrication Facility

Annual Report

June 2011 – May 2012

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Nanotools MicroFabrication Facility

Content

Executive Summary

In the fiscal year 2011-2012 income from user fees was $262,731. Compared to 2010/11, this is an effective 18% increase. **For a second year in a row, the McGill Nanotools Microfab is recovering all operating expenses from user fees.** The University and NanoQuebec support the cost of manpower at 100%. Average user fees amounted to $37.5/h.

After 4 years of strong growth nearly all outputs quantifiable with reasonable effort show a stabilization of usage in 2011/12. Usage is at 7004h, an increase of 1% compared to 2010/11. There were 50 PIs using the Microfab (42 in 2010/11), with 14 users using it for more than 100h (13 in 2010/11). 107 students worked in the Microfab (91 in 10/11), resulting in 52 publications (57 in 10/11), 8 patents (6 in 10/11), and 1 start-up (Sensoreal Inc). 44 HQP graduated with a project that had a major Microfab component (52 in 10/11), while 5 external companies used the Microfab (3 in 10/11). Given the competitive funding climate a remarkable high amount of new grants worth $ 3,925,476 ($2,669,150 in 2010/11) were acquired directly by the fab PIs, in addition to $3,700,000 as a result of FQRNT Regroupements Startegiques renewals and two new NSERC CREATE programs with important fab justification and research components. Very important for the long term sustainability of the fab operation was winning peer reviewed, competitive support for fab manpower from NanoQuebec: $140,000p.a. for two years. **The McGill Nanotools Microfab is now part of the Quebec Nanotechnology Core Infrastructure.** This positions the McGill Nanotools Microfab well for renewal of all NanoQuebec infrastructure support in 2013.

The 5th installment of the Hands-on Nanobiotechnology lecture and lab course was offered from Feb 20-24, 2012, attracting 26 students (11 from outside of McGill). A 6 pocket Ebeam evaporator from Angstrom Engineering was purchased with NSERC RTI funding and fully commissioned in 2011-2012.

A clear trend is observable in all the data: stabilization at a high level with reduced growth when compared to previous years. **The McGill Nanotools Microfab has reached steady state operation**. The data also shows that McGill Nanotools Microfab continuous to be core to the research of many, mainly recently hired, faculty in Engineering, Science and Medicine at McGill. The outside user base and usage is increasing slightly; with increased marketing by NanoQuebec this might lead to some growth in future years. The submitted CFI VII 'Nanotools II' proposal will substantially increase our capabilities, in particular for rapid prototyping and biomedical applications and is expected to lead to growth of life science users once implemented. We are currently establishing partnerships with the MNI as a bridgehead to attract life science and biomedical researchers to the fab. We continue to observe that companies are interested in the whole 'package': PI, HQP and access to excellent facilities. Indeed most companies access the McGill Nanotools Microfab via collaborative mechanisms such as NSERC Strategic projects, CRD or in other partnership agreements with McGill researchers.

Finally, it is noteworthy to point out the excellent team work of our fab staff: every day on average 4 different processes are performed by the users! This is a constant challenge to our staff in terms of equipment maintenance, operations stability, safety and training.

Organization

Academic Oversight

In November 2009, the position of Academic Microfab director was created. The academic Microfab director is responsible for:

- updating or creating policies
- supporting training and teaching opportunities
- enabling scientific and technological development
    1. Taking advantage of available expertise and capabilities (active/passive 'matchmaking')
    2. Identification of needs and what to do about it
    3. Coordination of capital equipment grants (CFI)
- developing in- and outreach initiatives
- ensuring financial stability of the Microfab
- evaluation of Microfab personal
- receiving and following up on suggestions and complaints about Microfab operations
- generate an annual report (accountability, transparency and information)

To achieve these goals, the academic director is supported by an Advisory Committee (AC). The AC provides feedback to the Microfab director, but has no executive decision power, which rests with the Microfab director.

Academic Microfab director:	Prof. Peter Grutter, Assoc. Dean of Res. & Grad. Educ. (Fac. of Science).
Advisory Committee:	Prof. David Juncker (Medicine)
	Prof. Thomas Szkopek (ECE)
	Prof. Srikar Vengallatore (Mech. Eng)
	Dr. Matthieu Nannini (Fab manager)

Achievements and key improvements

A major success for the Microfab was obtaining **$140,000 p.a. for 2 years from NanoQuebec** and is now a core part of the Quebec Nanotechnology Infrastructure. This will allow us cover all manpower costs as McGill reduces its support in the coming years and expand our efforts to provide services to the micro-nano bio community. The fund was opened at the end of December; a business plan was developed for the micro-nano bio community and is currently being implemented.

After extensive consultation with the microfab user community as well as other researchers at McGill a **CFI LOF Nanotools 2 for a total of $11.3M was submitted in April 2012**. This is a follow up proposal of the original Nanotools CFI and requests a fast prototyping suite, growth and characterization equipment needed to advance research, development and training. Competition results are expected in Nov. 2012.

The annual **Microfab user meeting** was held 15 April 2011 with more than 50 participants. In the spring of 2012 no meeting was organized due to many individual interactions necessary with many fab users to develop the CFI call VII Nanotools II proposal.

We started a series of **monthly lunch user meetings** every first Thursday of the month for students to discuss details of particular processes they developed. The aim of these meetings is to build and sustain the Microfab community, facilitate personal interactions, enable the exchange of information, and provide a forum for consultation between the Microfab team and users. Policies and procedures are discussed (and if necessary subsequently adapted).

List of user meetings:

Oct. 6th: Helgi Skulason on graphene on quartz, Au lines for RF (Szkopek group)

Nov 3rd: Andra St. Quintin on ebeam lithography (Kirk group)

Dec 1st: Paul-Vahe Cicek on SiC processing (el Gamal group)

Jan 12th: Roozbeh Safavieh on SU8 and two level DRIE (Juncker group)

Feb 2nd: John Li on DRIE processing (Fab Staff)

March 1st: Jerome LeBoeuf on Fabrication of Micro-crucibles for Vapor-Liquid-Solid Growth

Apr 5th: Victor Yu on InP and Graphlocon devices

Jun 7th: Chenxu Shao on fabrication of nanowire SNS junction (Gervais group)

The 5th installment of the **Hands-on Nanobiotechnology** lecture and lab course was offered from Feb 20-24, 2012. This year's course drew 26 participants, with 15 coming from McGill and the other 11 from Concordia, U de Montreal, Sherbrooke, and U of Ottawa, including 2 faculty members from McGill. Participants received basic instruction on microfabrication and each made their own wafers in the clean room. Microfluidic techniques and microcontact printing were demonstrated in the lab, as well as brainstorming sessions to help them design devices specific for their research. The keynote speaker was

Prof. Hatice Altug, of Boston University, who showcased exciting research in the in the field of photonic nanosensors. http://micronano.info has more details.

The Standing Committee on Finance of the House of Commons was hosted on Oct 5th. We explained some of our research, discussed financial issues and gave a hands-on tour of Juncker's nanobio facilities.

Figure: D. Juncker giving a presentation via Skype on nanobio research to the Standing Committee on Finance. Brian Jean (conservative caucus) and Justine Trudeau (liberal caucus) inspecting microfluidics devices fabricated in the McGill Nanotools Microfab by the Juncker group.

In 2011/12 the following **new policies were developed, communicated and implemented**. The general philosophy guiding these policies is to provide transparent and fair access to all users (major and casual, academic and industrial) and to nurture the vision of a shared, safe Microfab community where all users share responsibility, information and training.

- User Agreement, to be signed annually
- Afterhours access, including weekends

Finally, an annual **evaluation of all Microfab staff** was performed. The process consists of a self-evaluation followed by an evaluation by the supervisor, as specified in the job description. The Microfab manager is evaluated by the academic Microfab director; all staff members of this facility are evaluated by the Microfab manager. Reappointment of all staff was recommended. The manager and staff form a highly motivated, dynamic and hard working group.

Major new policies

All McGill Nanotools Microfab policies (including user fees) can be found at:

http://mnm.physics.mcgill.ca/content/policies

User Agreement:

McGill Nanotools Microfab staff is committed to providing an environment conductive to high-quality research and learning. To ensure that everyone knows their responsibilities, all members of the MNM community (students, staff, faculty, and industrial visitors) are asked to annually read and sign a McGill Nanotools User Policy Agreement outlining responsibilities and consequences for breaking rules.

The wording of the User Agreement can be found at:
http://mnm.physics.mcgill.ca/system/files/McGill%20Nanotools%20User%20Policies%20Agreement%202011-11-10.pdf

Weekend access policies:

The fab can be accessed during week-ends and National statutory holidays except for the Christmas break with the following conditions:

1. A plan of ALL experiments that "urgently" needs to be submitted 48h in advance (Thursday before 08:00). Fab staff can refuse weekend access if they feel that EHS might be compromised. Their decision is final and cannot be appealed.

2. All users (including buddy) need to pass an oral exam by the fab manager to ensure that they know about the EMO in case of danger for the tool or for their health. This will ensure an adequate training level of the user. This exam has to be renewed every 2 months. Set up an appointment with the fab manager.

3. Strictly enforced buddy system: always 2 knowledgeable users in the fab at all times.

4. The following processes are off-limits:

- AMP5000 (RIE, PECVD)
- Tylan (furnaces)
- HF and TMAH usage

5. Same user fees.

6. Doubling of penalties in case fab rules are not strictly adhered to (spot check via video)

7. Users are responsible of getting their access to the building during off-hours. Contact Louise Decelles chairsec.physics@mcgill.ca

Update on Manpower and Equipment

McGill Nanotools Microfab Operation Staff

Microfab Manager:	Dr. Matthieu Nannini
Technologist:	Don Berry
Equipment technologist :	John Li
Research Assistant:	Lino Eugene

Note: this list is only the clean room staff directly reporting to the fab manager. Several other FTE relevant for the operation of the Microfab (billing, repairs, IT) are paid for from departmental resources or funded by the Centre for the Physics of Materials through a FQRNT funded Regroupement Strategique in Advanced Materials (RQMP).

Changes in Tools

The following pieces of new equipment were purchased and commissioned in 2011-2012:

- 6 pocket Ebeam evaporator from Angstrom Engineering. Model: NexDep

No piece of equipment was deemed obsolete by the community.

Outcomes: Publications, HQP and Grants

Summary

After 4 years of strong growth nearly all outputs quantifiable with reasonable effort shows a steady output and a slowdown of growth to the last two years. 107 students worked in the Microfab (91 in 10/11), 52 publications (57 in 10/11), 8 patents (6 in 10/11), 42 invited talks, 1 start-up (Sensoreal Inc., created by Roozbeh Safavieh from the Juncker group, 44 HQP graduated with a project that had a major Microfab component (52 in 10/11) and 5 external companies used the Microfab (3 in 10/11). New grants worth $ 3,925,476 ($2,669,150 in 10/11) were acquired directly by the fab PIs, in addition to $3,700,000 as a result of FQRNT Regroupements Strategiques renewals and two new NSERC CREATE programs.

Publications (including Patents and Disclosures)

In 2011/12, at least 52 peer reviewed publications and 8 issued or filed patents resulted from work with an intensive Microfab component (some of the minor Microfab users did not provide an annual report). This is a leveling off of the trend observed in the past few years: 57/6 publications/patents in 2010/11, 41/2 in 2009/10 and 21/7 in 2008/09. Appendix A gives the detailed titles, authors and references (note that publications, for annual consistency reasons, were only counted in a given calendar year, whereas all other data is from June 2011- May 2012.

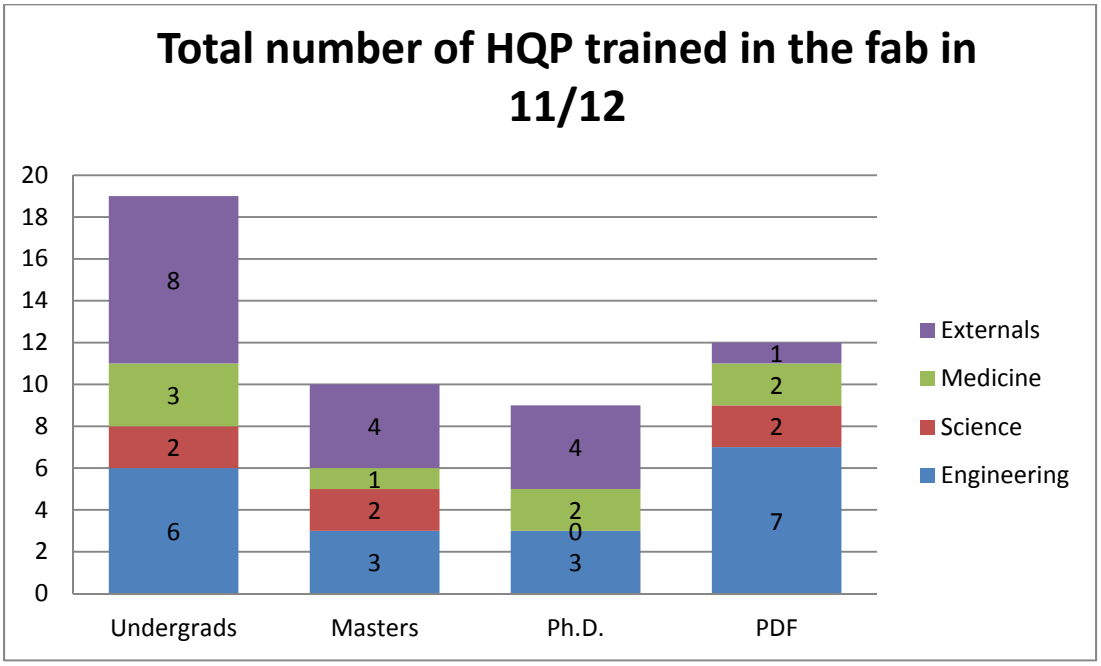
Graduated HQP

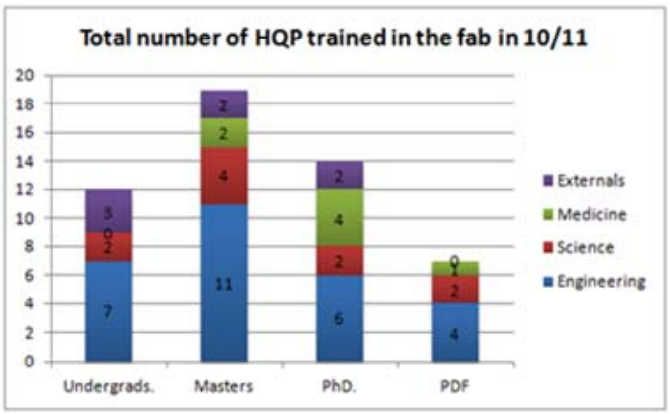
The total number of HQP trained in the Microfab has also stabilized at 107 (compared to 91 in 2010/11, 64 in 2009/10 and 57 (2008/09)). Again a large, stable number of HQP graduated with a major component of their work being performed in the Microfab: 44 compared to 52 in 2010/1 (see table below and appendix for details).

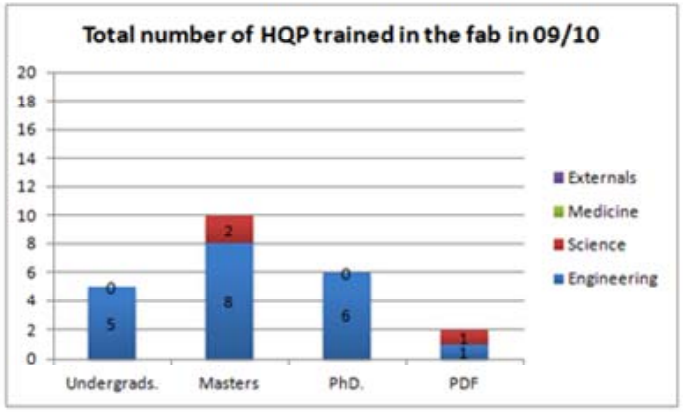
Table: Number of students graduating from the fab as provided by the PIs (with the affiliations given in brackets: *#eng.-#science-#medicine-#externals*).These numbers are underestimates, as not all PIs provided a report:

HQP category	**2011/12**	**2010/11**	**2009/10**
Undergraduates	13(6-7-0-0)	12 (7-2-0-3)	5 (5-0-0-0)
Masters	10(3-2-1-4)	19 (11-4-2-2)	10 (8-2-0-0)
Ph.D.	9(3-0-2-4)	14 (6-2-4-2)	6 (6-0-0-0)
PDF	12(7-2-2-10)	7 (4-2-1-0)	2 (1-1-0-0)

HQP trained in fab:







Research Grants acquired due to access to fab

The total of ***new*** individual grants and contracts directly linked to the fab acquired by PIs (excluding Discovery Grants) had a value of **$ 3,925,476** - an increase of more than 50% from of $ 2,669,150 in 2010-11 (and approximately 200% from $ 1,339,826 in 2009-10)**.** Of this, $428,200 was directly acquired for the fab (through a NSERC RTI Equipment grant and the Quebec Nanotechnology Infrastructure program (NanoQuebec)). An **additional total of $3,700,000** not included in the total above were acquired by 2 new CREATE programs in Neuroengineering and Nanobiomachines as well as a FQRNT Regroupement Strategique (INTRIQ), all three with major fab components. The distribution across faculties is similar to last year: 52% from engineering, 22% from science and medicine each and 3% from outside of McGill. The trend to a more even distribution across faculties is continuing the trend detected in 2011. Note that in 2009/10 the PIs of these grants were almost exclusively from the faculty of engineering.

Budgetary report

Fiscal year 2012: May, 1st 2011 to April 30th, 2012

Summary:

Year	Total expenses	Total invoiced	Difference
FY12 Q1	32 038.74 $	78 180.42$	+ 46 142.42$
FY12 Q2	70 371.33$	75 836.46$	+ 5 465.13$
FY12 Q3	57 572.83 $	52 218.89$	-5 353.94$
FY12 Q4	81 612.14 $	58 884.22$	-22 727.92$
Total	**241 595.04 $**	**265 119.99$**	**23 525.69$**
Year	Total expenses	**Total invoiced**	**Difference**
FY12 Q1	32 038.74 $	71 180.42$	+ 39 141.68 $
FY12 Q2	70 371.33$	73 447.08$	+ 3 075.75$
FY12 Q3	57 572.83 $	52 198.02$	- 5 374.81$
FY12 Q4	81 612.14 $	58 884.22$	-22 727.92$
Total	**241 595.04 $**	**262 730.61$**	**21 136.31$**

History

	Total expenses	Total invoiced	Difference
FY08	137 038,35 $	83 184,13 $	- 53 854,22 $
FY09	115 529,12 $	77 432,85 $	- 38 096,19 $
FY10	147 748,18 $	140 843,08 $	- 6 905,10 $
FY11 (11 months)	181 131.58 $	207 265.31$	+26 133.72$
Total	**241 595.04 $**	**265 119.99$**	**23 525.69$**

Expenses Details for FY12

	$$	FY12	FY11	FY10	FY09	FY08
PM-Repair: includes equipment and facilities repair expenses	82 837.77 $	34.3%	42.0%	42%	51.8%	60.9%
Consumables: includes chemicals (acids, solvents, litho…), materials, substrates, …	93 642.59 $	38.8%	41.4%	38%	40.5%	25.6%
Purchase: small tools, fab improvements, MDEIE installs	38 739.49 $	16%	7.6%	5%	1.8%	8.8%
Office: includes NCS charges, computer and office supplies, IT improvement	12 034.26 $	5%	7.0%	10%	5.3%	2.5%
Travel	1 170.00 $	0.5 %	1.0%	5%	-	-
External: work done in other core facilities	5 399.26 $	2.2%	0.4%	1%	0.3%	1.6%

Courrier	2 724.67 $	1.1%
Broker	5 047.00 $	2.1%

Comment: The “purchase” category is twice as much as last year because 20 000$ were spent on the new EbeamEvap as the NSERC RTI didn’t entirely covering all costs (taxes, shipping).

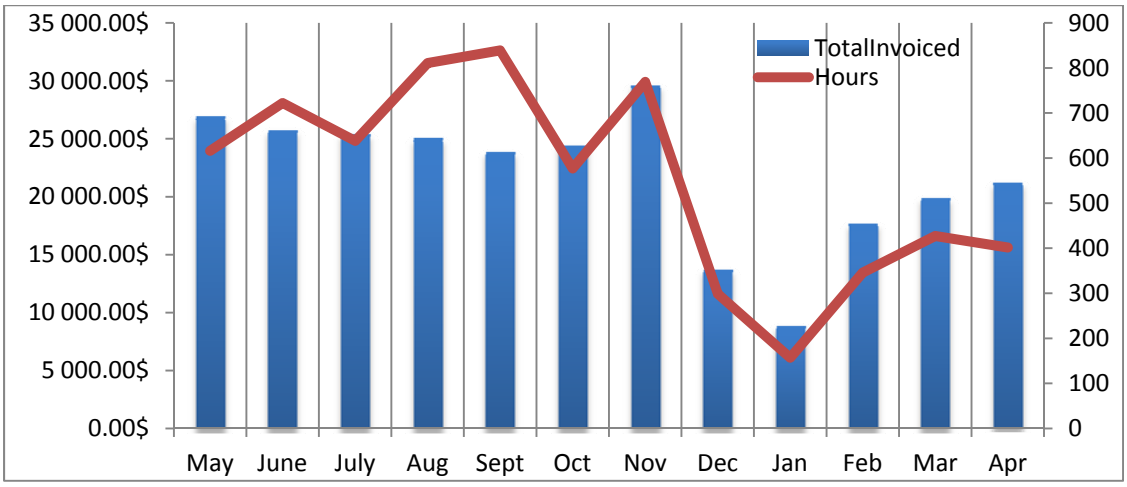
Note that all manpower related cost is covered by McGill and NanoQuebec funding, the budget above is only for operations.

Revenues

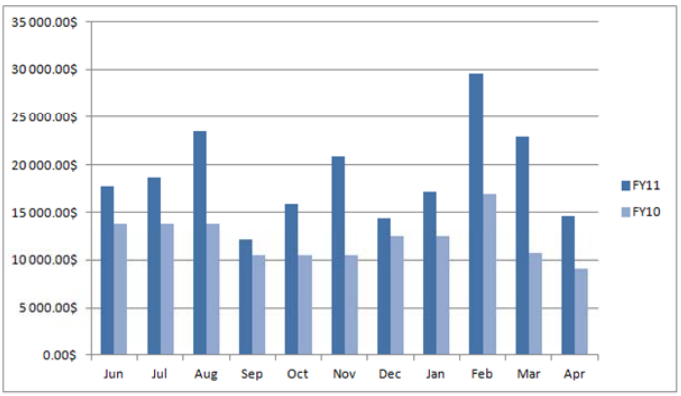
Total revenues from May-11 to April-12: $262,730.61 Compared to 2010/11, this is an effective 18% increase.[1] Whereas the regular base user fee is $50, the average hourly user fee (total income divided by total billed hours) is only $37.51. This is mainly due to the soft cap set at $1000/month after which only 25% of the costs are charged, benefitting major users with many HQP using the fab.[2] The philosophy for this soft cap is that major users contribute to the fab in terms of process development and that their students often also coach other students. With this user fee structure the McGill Nanotools Microfab is covering 100% of the cost of operation for a second straight year.

The following chart summarizes revenues and billed hours per month for the FY 2011/12 (total number of PIs is 50). We took a severe drop in revenues for Dec. and Jan. mainly due to 2 factors:

- Christmas break + 3 weeks down for the EBeamEvap (oil backstreaming in cryo pump)
- EBL system down mid Nov. to the end of Feb. due to HV issues related to climate control.



Revenues for the FY 2010/11 and 09/10 (total number of PIs 42):



[1] In 2010-11 (11 months fiscal year) revenues were $ 207, 265.31. If pro-rated to 12 months this corresponds to $226,107. In 2011-12 our revenues were $262,730.61, an effective 18% increase.

[2] Details of user fee structure can be found at http://miam2.physics.mcgill.ca/?q=content/rates

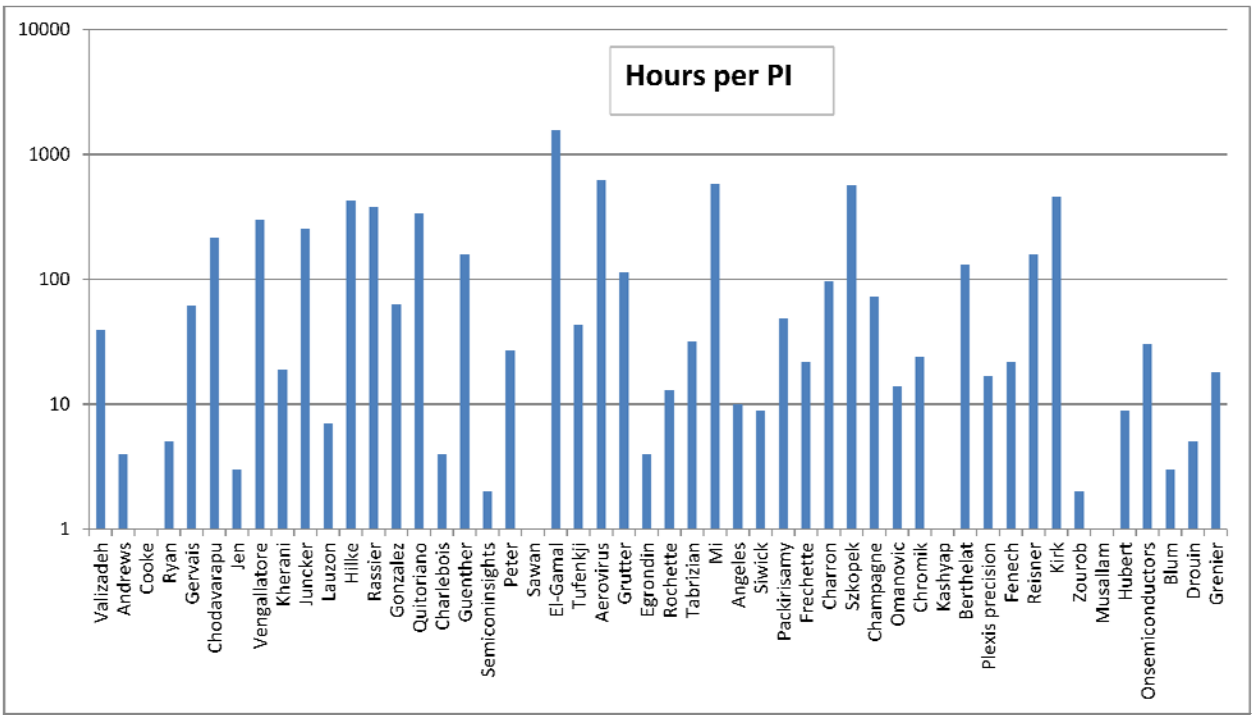
Usage

In 2011/12 the Microfab generated **7004 billable hours**, a slight 1% increase over last year with 6300h (note, the 2010/11 fiscal year had 11 months only, thus usage prorated to 12 months would amount to 6900h). In 2008/09 we had a little more than 2300 billable hours.

The **50 PIs** sent a **total of 107 HQP** to work in the Microfab, compared to 42 PIs who sent a total of 91 HQP in FY 2010/11 – a 19% increase in the number of PIs and 17% increase in the number of HQP. On average, each HQP spent nearly 65h (76 h in 2010/11) in the Microfab.

We have sustained the **number of major** users at 14 (11 last year), including one with more than 1500h. A major PI is defined as a PI who use the Microfab more than 100 h per year.

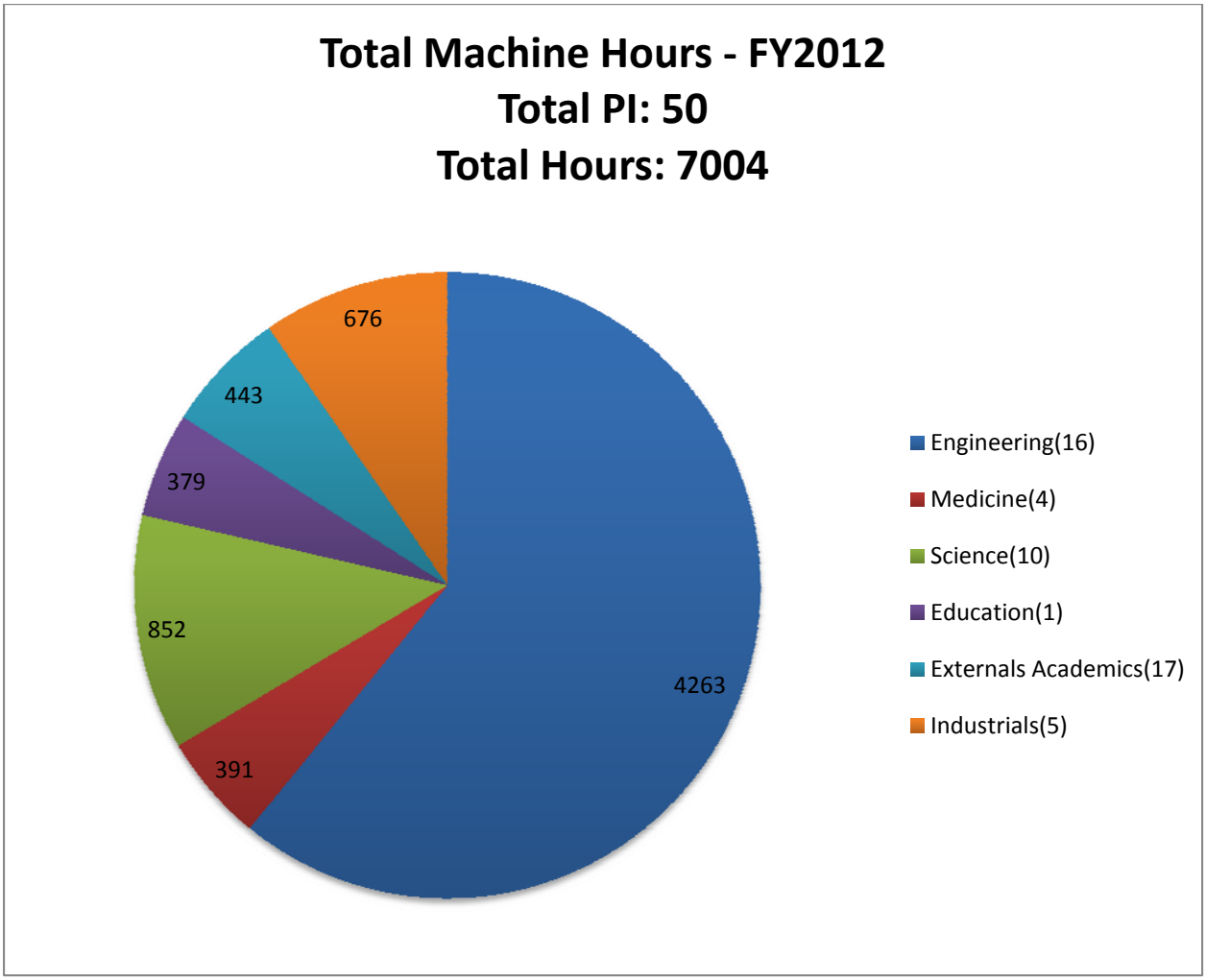
These numbers demonstrates that the user base of the Microfab is now broad and and that it will ensure sustainability.



Total hours per PI for FY 2009/10. Note the broad, sustainable basis of major users with more than 100h.

Usage breakdown according to faculties:

The major user in terms of hours is the faculty of Engineering. Medicine, Science and external users are similar, each about 10-20% of the usage by engineering. A slight decrease in usage was observed for industrial users (due mainly to Aerovirus Technologies very high usage in 2010/11). The total number of PIs increased slightly by 20%, mainly due to members from Engineering and science.



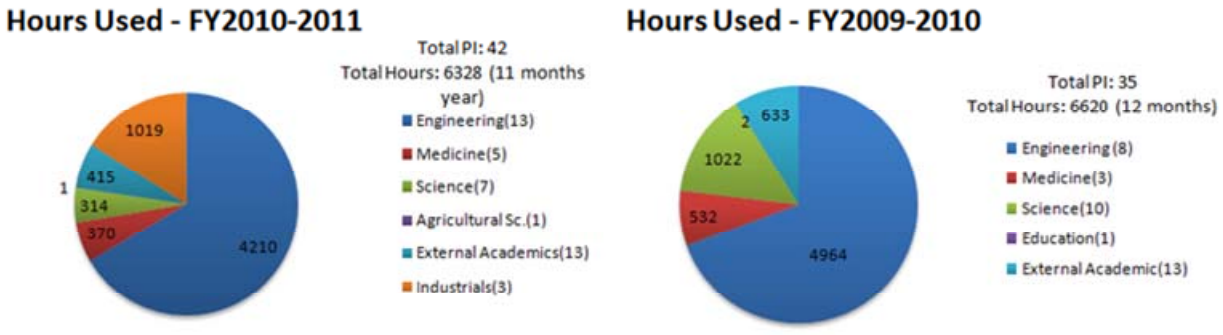


Figure 1: Breakdown of hours of Microfab facility usage for fiscal years 2011/2012, 2010/2011 and 2009/2010. The number of principal investigators (PIs) for each category is also given in brackets. PIs affiliated with the Faculties of Engineering are major users, with Medicine, Science and external industrial usage also noteworthy.

The total number of HQP trained in the Microfab increased by 18% from 91 to 107 in 2011-12, thus increasing slightly after a 42% increase last year. Roughly half these HQP are engineering students.

It is noteworthy that for a 240 workday year (48 weeks of operation), assuming an 8 hour day and a total of 7004h billed hours, **on average there are 3.7 HQP in the Microfab at all the times**. This translates to 4 different processes being executed on a given day in the Microfab, a major challenge in terms of support and scheduling of equipment.

The overall number of HQP trained in the fab increased by 18% compared to the last period:

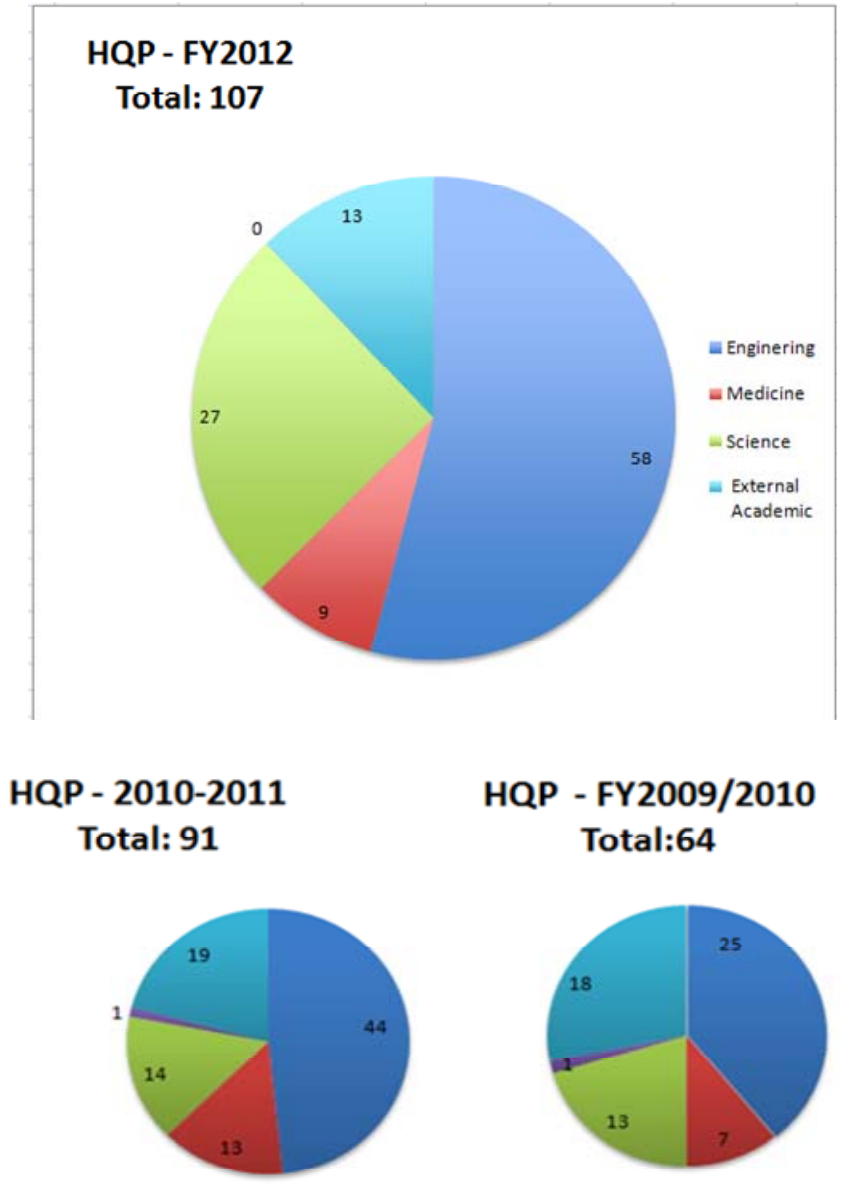


Figure 2: Number of HQP using the Fab for fiscal years 2009/10, 2010/11 and 2011/12, broken down by Faculty affiliation. The overall number of HQP trained in the fab increased by 18% compared to the last period.

External (non-McGill) Usage:

External Academic users:

Alexandre Champagne	Physics	Concordia University
M. Packirisamy	ECE	Concordia University
Pouya Valizadeh	ECE	Concordia University
Etienne Grondin	Fab. Manager	Ecole Polytechnique de Montreal
Raman Kashyap	Eng. Physics	Ecole Polytechnique de Montreal
Yves-Alain Peter	Eng. Physics	Ecole Polytechnique de Montreal
Mohamad Sawan	Eng. Physics	Ecole Polytechnique de Montreal
Mohammed Zourob	EMT	INRS
Serge Charlebois	ECE	U. de Sherbrooke
Dominique Drouin	ECE	U. de Sherbrooke
Luc Frechette	Mech. Eng.	U. de Sherbrooke
Olivier Grenier	Fab. Manager	U. de Sherbrooke
Frédéric Charron	Biochem.	Institut de recherches cliniques de Montréal
Marianne Fenech	Biomed. Eng.	U. of Ottawa
Axel Guenther	Biomedical Eng.	U. of Toronto
Nazir Kherani	Mat. Eng.	U. of Toronto
Dumitru I. Caruntu ,	Mech. Eng.	U. of Texas-Pan American, Edinburg, TX, USA

Industrial Usage:

Companies which used the fab directly in 2011-12:

Aerovirus Technologies (Ste Hyacinthe QC) has a research contract with the fab to develop a prototype sensor.

PlexisPrecision (St-Laurent QC) has a service contract with the fab to characterize laser micromachined parts. A project involving ebeam lithography for the fabrication of polarizer was also investigated.

UBMInsights (Ottawa, ON) has a service contract with the fab for the deposition of thin Titanium film and subsequent dicing of the wafers.

OnSemiconductors OnSemiconductors (Burlington ON) has a research contract with the fab for dry etching of a TiW/Al/TiW layer.

Horiba Jobin Yvon Yvon (Paris, FRA) has a service contract with the fab for the deposition of parylene C on aluminum parts.

We observed that companies are not very interested in directly accessing the Microfab. A strong increase in academia-industry collaborations and partnerships leads to the conclusion that companies prefer to access the McGill Nanotools Microfab via collaborative mechanisms such as NSERC Strategic projects or in other partnership agreements with McGill researchers instead of directly using it. This is corroborated by informal and non-representative discussions with several companies: they are interested in the whole 'package': PI, HQP and access to excellent facilities. In one case (Boston Microsystems) the attractive cost structure and the availability of a unique tool (spray coater), as compared to Microfabs in the Boston area, was an important factor in deciding to engage in a collaboration at McGill.

The following companies have used the Microfab in 2011/12: (collaborating PI indicated in brackets)

MEMS-Vision Inc. is a spin-off company from McGill (Mourad El-Gamal).

Boston Microsystems (Research collaboration, Srikar Vengallatore)

General Motors of Canada, Inc. (Strategic Grant and Collaborative Research Grant, both S. Vengallatore in collaboration with Prof. Luc Frechette at Universite de Sherbrooke. The combined value of these grants is about $1 million over four years (2008-2011)

General Motors of Canada, Inc. (M. Cerruti and T. Szkopek) NSERC CRD entitled 'Graphene-Sn nanocomposites for Li-ion battery anodes' with $19,130 cash and $25,910 in-kind support from GM.

Bombardier and Thales (industrial sponsors of a CRIAQ project entitled "Data Networks and Smart Sensors for Safety-Critical Avionics Applications". Mourad El-Gamal)

Reflex Photonics Inc. (Montreal) committed in-kind support for NSERC Strategic grant entitled 'Direct integration of microtube lasers on silicon' (PI Andrew Kirk, with Z Mi and D.V. Plant), $136,000 per year of funding from NSERC (2009-2011)

DALSA Semiconductor (Bromont) has committed $20,000 per year of funding as part of a NanoQuebec project entitled 'Integrated polymer electro-optic switches', (PI Andrew Kirk, with Mark Andrews), leveraging $66,667 per year of funding from NanoQuebec (2010-2012)

ICP Solar Technologies and Silonex Inc.
'Full-Solar-Spectrum InGaN Tandem Solar Cells on Si' (Z. Mi)

DNA LandMarks Inc.
'Ultrasensitive InN Nanowire Biosensors' (Z. Mi, P. Grutter, R. Sladek)

Outside, non-academic users:

Similar to industrial users, several organizations sponsor applied research with a strong fab component:

Canadian Space Agency and NanoQuebec.
'CMOS integrated Nitride Nanowire Array Based Bacterial Nanosensor' (V.P. Chodavarapu and 3 others). 2009-2011 for $261,000.

Sandia National Laboratories (USA):
'Nanoelectronics Experiments Using Coulomb Drag to Study Coupled One-Dimensional'
(G. Gervais, US$ 22,068)

Genome Québec
'Towards a Portable and Fully Automated SPR-Based Digital Microfluidics Array Platform Integrating Diffractive Optical Elements for Genomics and Proteomics' (M. Tabrizian & 2 others, $133,333 p.a.)

Canadian Institute for Photonic Innovations
'Nanoporous silicon catheter device with real-time optical monitoring of bacterial contaminants during hemodialysis', V.P. Chodavarapu (PI) and 1 other, $31,900

Defence Research and Development Canada
'Antimony-Based Long Wavelength Self-Organized Quantum Dot Lasers Alternative Energy: Solar-to-Hydrogen' (Z. Mi and H. Guo, $ 110,000)

Major Success Story

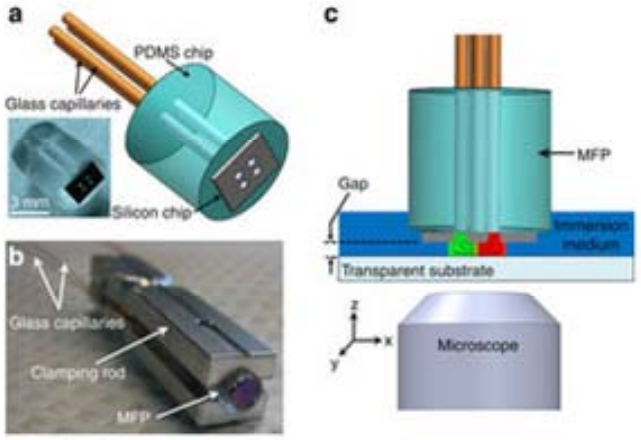
Starting with this annual report we will highlight one or two major achievements with key input from the McGill Nanotools Microfab.

Research:

The research group of **David Juncker** published a high impact paper which was highlighted in more than 60 news and scientific websites, notably on Futurity, Nature Asia-Pacific, Science Daily, Medical Device Daily, and PhysOrg. See e.g. http://www.synbio.org.uk/wetware-news/2186-new-microfluidics.html

The lead student on this project Mohammad Qasaimeh was also awarded the FRSQ **etudiant-chercheur etoile** for May 2012 based on this work.

'Microfluidic quadrupole and floating concentration gradient'
M.A. Qasaimeh, T. Gervais & D. Juncker
Nature Commun. **2**, 464 (2011)
DOI: 10.1038/ncomms1471,



Microfluidic devices offer precise, small-scale methods of delivering fluids to organisms, tissues, and cells. A microfluidic quadrupole, as developed by David Juncker and his colleagues, provides a quickly-adjustable concentration gradient in a setup that is designed to minimally disturb cells. Such an apparatus could give researchers a system for exposing cells to signaling molecules, for instance, and watching cells' reaction right in the dish.

Interactions with non-academic users:

Y.-A. Peter (Ecole Polytechnique) designed, and fabricated an optical micro-accelerometer for microsatellite navigation system in collaboration with **MPB Communications Inc. and the Canadian Space Agency:**

'VOA-Based Optical MEMS Accelerometer', K. Zandi, J. Zou, B. Wong, R. V. Kruzelecky, and Y.-A. Peter, IEEE/LEOS International Conference on Optical MEMS and Nanophotonics, Istanbul, pp. 15-16, 2011.

Training:

The quality of training offered was exemplified by Michael Menard, who graduated from A. Kirk's group in 2009 and was appointed as an Assistant Professor at UQAM in 2011.

Outlook

In the 2011 Outlook, the following objectives for 2011-12 were defined:

1. **Manpower Funding**: increase the level of external funding through grant applications to NanoQuebec and NSERC MRS.
   NanoQuebec funding was obtained. An application involving all fabs and led by McGill (A. Kirk) was submitted to the NSERC MRS program; this program was however cancelled.
2. **Usage**: increase the level of usage by increasing outreach efforts to the community and possibly hire a business development person to attract more external users.
   This was part of the NanoQuebec proposal, but was rejected by the peer review committee in part due to limited resources and in particular because NanoQuebec has opened a position with specifically this mandate.
3. **Equipment**: apply to CFI VII for the upgrade of our toolset in order to stay competitive and state-of-the-art in the area of microfabrication.
   The proposal was submitted; results are expected in November 2012
4. **Operations**: improve microfab operations at the administration, tool maintenance and training level in terms of efficiency and effectiveness.
   Ongoing by being responsive to user needs and requests. An example is the recent development of access policies for weekend usage.

In 2012-13 the McGill Nanotools Microfab objectives are:

1. **Funding**: with the announced reduction of direct financial support by McGill we need to develop a long term financial plan. An essential part will be the expansion of services to the life science community, which will enable larger and more stable user income. Success in the current CFI VII competition will be a key element in addition to current discussions with the Montreal Neurological Institute on expanding services.
2. **Infrastructure**: Implement the CFI requested upgrade of the Nanotools infrastructure.
3. **Usage**: increase the usage by researchers from the life sciences by hiring dedicated manpower funded from current NanoQuebec support.
4. **Operations**: improve microfab operations at the administration, tool maintenance and training level in terms of efficiency and effectiveness.

Appendices

Papers in 2011 that used some aspect of the McGill Nanotools Microfab:

[1] M. Qasaimeh, T. Gervais & D. Juncker
Microfluidic quadrupole and floating concentration gradient,
Nature Commun. 2, 465 (2011)

[2] W. Luo, M. Pla-Roca & D. Juncker
Taguchi design-based optimization of sandwich immunoassay microarrays for detecting breast cancer biomarkers,
Anal. Chem. 83 (14), 5767–5774 (2011)

[3] R. Safavieh, G. G. Zhou & D. Juncker
Microfluidics made of yarns and knots: From fundamental properties to simple networks and operations,
Lab chip 11, 2618 - 2624 (2011)

[4] B. Corgier & D. Juncker
Polymeric Microfabricated Electrochemical Nanoprobe with Addressable Electrodes
Sensors & Actuators B, 157: 691-696 (2011)

[5] H. Li, R. F. Leulmi and D. Juncker
Hydrogel droplet microarrays with trapped antibody-functionalized beads for multiplexed protein analysis
Lab Chip 11, 528 - 534 (2011)

[7] H. P. T. Nguyen, S. Zhang, K. Cui, X. Han, S. Fathololoumi, M. Couillard, G. A. Botton, and Z. Mi, "p-type modulation doped InGaN/GaN dot-in-a-wire white light emitting diodes monolithically grown on Si(111)," Nano Lett., vol. 11, 1919, 2011.

[8] D. Wang, A. Pierre, Md. Kibria, K. Cui, X. Han, K. Bevan, H. Guo, S. Paradis, H. Abou-Rachid, and Z. Mi, "Wafer-level photocatalytic water splitting on GaN nanowire arrays grown by molecular beam epitaxy," Nano Lett., vol. 11, 2353, 2011.

[9] Q. Li, K. R. Westlake, M. H. Crawford, S. R. Lee, D. D. Koleske, J. J. Figiel, K. C. Cross, S. Fathololoumi, Z. Mi, and G. T. Wang "Optical performance of top-down fabricated InGaN/GaN nanorod light emitting diode arrays," Opt. Exp., vol. 19, 25528, 2011.

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[14] M. C.-K. Cheung, P. J. R. Roche, M. Hajj-Hassan, A. K. Kirk, Z. Mi, and V. Chodavarapu, "Controlling optical properties and surface morphology of dry etched porous silicon," J. Nanophoton., vol. 5, 053503, 2011.

[15] M. César, Y. Ke, W. Ji, H. Guo, and Z. Mi, "Band gap of $In_xGa_{1-x}N$: a first principles analysis," Appl. Phys. Lett., vol. 98, 202107, 2011.

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[19] Z. Tian, V. Veerasubramanian, P. Bianucci, S. Mukherjee, Z. Mi, A. G. Kirk, and D.V. Plant 'Single rolled-up InGaAs/GaAs quantum dot microtubes integrated with silicon-on-insulator waveguides', OSA Optics Express 19, pp 12164-12171, 2011

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[22] Z. Tian, V. Veerasubramanian, P. Bianucci, Z. Mi , A. G. Kirk, and D. V. Plant, , 'Characterization of InGaAs/GaAs microtubes at transparent wavelengths', , Proc. IEEE Photonics Conference 2011, Arlington, VA, p. 745-746, 2011

[23] Yongyuan Zang1, Dan Xie2, Xiao Wu2, Yu Chen2, Yuxuan Lin2, Mohan Li3, He Tian2, Xiao Li4, Zhen Li4, Hongwei Zhu4,5, Tianling Ren2, and David Plant1 "Enhanced photovoltaic properties in graphene/polycrystalline BiFeO3/Pt heterojunction structure" Applied Physics Letters 99, 132904 (2011)

[24] Hydrodynamics of Superfluid Helium in a Single Nanohole
M. Savard, G. Dauphinais and G. Gervais,
Phys. Rev. Lett. 107, 254501 (2011).

[25] "Experimental Review of Graphene", Daniel R. Cooper, Benjamin D'Anjou, Nageswara Ghattamaneni, Benjamin Harack, Michael Hilke, Alexandre Horth, Norberto Majlis, Mathieu

Massicotte, Leron Vandsburger, Eric Whiteway, and Victor Yu,
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Physics, 2011, 501686 (2011).

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V. Yu, E. Whiteway, J.
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µPIV Blood microflow velocity profile measurements:
Comparison of the use of fluorescent particles versus RBC as tracer particles.
The Society of Rheology, 83rd Annual Meeting, Cleveland, OH, USA (October 2011), p.13.

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"Low-stress, CMOS-compatible silicon carbide surface micromachining technology part-I: process development and characterization,"
Journal of Microelectromechanical Systems, pp. 720 - 729 (10 pages) 2011.

[29] F. Nabki, T. A. Dusatko, P.-V. Cicek, and M. N. El-Gamal, "Low-stress, CMOS compatible silicon carbide surface micromachining technology part-II: beam resonators for MEMS above-IC," the Journal of Microelectromechanical Systems, pp. 730 - 744 (14 pages), June 2011.

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"A 5V MEMS gyroscope with 3 aF/degree/s sensitivity, 0.6 degree/root_square(Hz) mechanical noise and drive-sense crosstalk minimization,"
IEEE International Conference on Microelectronics (ICM Dec.'11), 4 pages, December 2011.

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"An accurate model for fluid loading on circular CMUTs",
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Optical detection system for probing cantilever deflections parallel to a sample surface.

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"110 GHz measurement of large-area graphene integrated in low-loss microwave structures",
Appl. Phys. Lett. 99, 153504 (2011).

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"Chemical vapor deposition synthesis of graphene on copper with methanol, ethanol, and propanol precursors"
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"Controlling optical properties and surface morphology of dry etch xenon difluoride porous silicon,
SPIE Journal of Nanophotonics, vol.5, iss. 1, art. 053503, 2011.

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"Ultra-thin Porous Silicon Membranes Fabricated using Dry Etching",
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"CMOS Imaging of Temperature Effects of Pin-Printed Xerogel Sensor Microarrays",
IEEE Transactions on Biomedical Circuits & Systems, vol. 5, iss. 2, pp. 189-196, 2011.

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"Design methodology for a Rankine microturbine: thermomechanical analysis and material selection,"
IEEE/ASME Journal of Microelectromechanical Systems, vol. 20, pp. 339-351.

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IEEE/ASME Journal of Microelectromechanical Systems, vol. 20, pp.720-729.

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"A microcantilever platform for measuring internal friction in thin films using thermoelastic damping for calibration,"
IEEE/ASME Journal of Microelectromechanical Systems, vol.20, pp. 764-773.

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“Controlling damping and quality factors of silicon microcantilevers by selective metallization,”
Journal of Micromechanics and Microengineering, vol. 21, art. no. 105010 (7 pages)

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“Patterning nanomaterials on fragile micromachined structures using electron-beam lithography,”
Materials Research Society Symposium Proceedings, vol. 1299, pp. 61-66.

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J.-B. Lalanne, W. Paul, D. Oliver, and P. Grutter
Rev. Sci. Instr. 82, 116105 (2011)

[50] Refined tip preparation by electrochemical etching and UHV treatment to obtain atomically sharp tips for STM and FIM
T. Hagedorn, M. El Ouali, Y. Miyahara and P. Grutter
Rev. Sci. Instr. 82, 113903 (2011)

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S. Fostner, A. Tekiel, J. Topple, Y. Miyahara and P. Grutter
Nanotechnology 22, 465301 (2011)

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A. Labuda and P. Grutter
Rev. Sci. Instr. 82, 013704 (2011),
Virtual J. Nanoscale Science & Technology, January 31 (2011)

Patents and Invention Disclosures 2011:

Method and Devices for multiplex microarray microfluidic analysis of biomolecules
H. Li, D. Juncker
US61/528792 US provisional filed Aug. 30th 2011

Microfluidic System using capillary effects
R. Safavieh D. Juncker
US61/528853 US provisional filed Aug. 30th 2011

Low temperature ceramic microelectromechanical structures
F. Nabki, T. Dusatko, M. N. El-Gamal, and S. Vengallatore
US Patent Issued # 8,071,411 B2, December 2011.

Lateral gap creation technique for a low temperature SiC process
F. Nabki and M. N. El-Gamal,
US Patent Application filed, January 2011.

Method and Optical Component for Guiding Light Towards Cantilevers in Constrained Spaces
D.E. Rassier, A. Labuda
US Utility Patent Application, US 13/097,197, Date filed: April 29th 2011.

Portable Phase Fluorometric Biological and Chemical Sensor System
V. P. Chodavarapu and D. S. Daivasagaya,
Invention Disclosure to McGill Office of Technology Transfer,
United States Provisional Patent, Filed September 12, 2011.

Method for Optimizing the Signal to Noise Ratio of Optical Beam Deflection Systems and Apparatus Thereof
A. Labuda, P. Grutter
ROI submitted Feb 2010, 11 Jan. 2011 provisional US application number: US 61/431,596

Automatic calibration of the dissipation signal of an atomic force microscope that uses a frequency modulation mode of operation
P. Grutter, Y. Miyahara, A. Labuda, W. Paul
McGill ROI 11076, 9.3.2011, license/patenting being negotiated with Nanonis GmbH (CH)

New Start-up Companies 2011

Sensoreal Inc.
Roozbeh Safavieh (Juncker group)

Graduated HQP 2011

1. Undergraduates who used the fab:

Engineering: (10)
Adrien Pierre (Z. Mi)
Amir Helmy (Z. Mi)
Andy Shih (Z. Mi)
Nick Hemsworth (A. Kirk)
Sina Dhane (A. Kirk)
Songzhe Wang (A. Kirk)
Galen Church (M. El-Gamal)
Hamza Bari (M. El-Gamal)
Tejas Deshpande (T. Szkopek)
Daisy Daivasagaya (V. Chodavarapu)

Science: (7)
Edward Wong (A. Gonzales)
Kade Head-Marsden (B. Siwick)
Yun Chu (G. Gervais)
Allen Leary (M. Hilke)
Wayne Yang (M. Hilke)
Hannes Boeckmann (M. Hilke)
Simon Bernard (M. Hilke)

2. Graduated M.Sc. and Ph.D.:

Engineering: (6)
Sandrine Filion-Cote (A. Kirk)
Andra St Quentin (A. Kirk)
Holger Strauss (R. Chromick)
Ali Taghvei (M. El-Gamal)
G. Sosale (S. Vengallatore)
N. Shalabi (S. Vengallatore)

Science: (3)
Guillaume Dauphinais (G. Gervais)
Carolyn Young (M. Hilke)
Alex Klotz (W. Reisner)

Medicine: (3)
Khali Heileman (M. Tabrizian)
Tohid Fatanat-Didar (M. Tabrizian)
Amir Foudeh (M. Tabrizian)

External: (8)
Joshua Island (A. Champagne, Concordia)
Rym Mehri (M. Fenech, Ottawa)

Nona Amadi (M. Fenech, Ottawa)
Omemeah Gliah (M. Fenech, Ottawa)
Katie Pitts (M. Fenech, Ottawa)
Kazem Zandi (Y.-A. Peter, Ecole Polytechnique de Montreal)
Antoine Lablanc-Hotte (Y.-A. Peter, Ecole Polytechnique de Montreal)
Xueling Quan (P. Grutter & A. Boisen, DTU)

3. Graduated PDF and Technician:

Engineering: (7)
Defa Wang (Z. Mi)
Hieu Nguyen (Z. Mi)
Pablo Bianucci (Z. Mi)
Kai Cui (Z. Mi)
Saeed Fathololoumi (Z. Mi)
Philip Roche (A. Kirk)
D. Almecija (S. Vengallatore)

Science: (2)
Heide Ibrahim (Banting Post-Doctoral fellow) (B. Siwick)
Xiaoqing Zhou (G. Gervais)

Medicine: (2)
Jamal Daoud (M. Tabrizian)
Arghavan Shabani (M. Tabrizian)

External: (1)
Pablo Bianucci (Y.-A. Peter, Ecole Polytechnique de Montreal)

Grants and contracts:

The total of ***new*** grants and contracts directly linked to the fab had a value of **$7,625,476.** This sum *excludes* NSERC Discovery Grants. This includes a total of $3,700,000 by 2 new CREATE programs in Neuroengineering and Nanobiomachines as well as a FQRNT Regroupement Strategique (INTRIQ), all three with major fab components. $428,200 was directly acquired for the fab (through a NSERC RTI Equipment grant and the Quebec Nanotechnology Infrastructure program (NanoQuebec)).
Note: all $ values indicated below are the total values.

Grants directly for the Microfab:

NSERC Research tools and instruments
Electron beam deposition system for multi-user nanofabrication facility
$148,200
Andrew Kirk (PI) and 9 others

Quebec Nanotechnology Infrastructure (NanoQuebec)
McGill Nanotools Microfab (MNM)
Peter Grutter (PI) and 9 others
$ 280,000 (2011-13)

NSERC:

Strategic Project Grant
Ultrahigh-efficiency phosphor-free InGaN/GaN dot-in-a-wire white light emitting diodes monolithically grown on silicon
Z. Mi (PI), G. Botton, H. Guo, and I. Shih
$ 453,000 (2011-2014)

Strategic Project Grant
Inexpensive, high-efficiency solar cells,
Nate Quirianio
$365,100 (2011-2013)

Strategic Project Grant
Toxicity, transformations and transport of engineered nanoparticles in soils: New approaches to detect and characterize environmental risks
N. Tufenkji + 4 others
$474,078 (2011-13)

Research Network on Bioactive Paper - SENTINEL
Development of fiber and filter paper based platforms for bacteria and virus detection and capture in water matrices
N. Tufenkji + T.G.M. van de Ven
$340,000(2011-14)

Idea to Innovation (I2I)
Snap Chip: Portable System for Miniaturized, Multiplexed Immunoassays
Juncker, David (PI)
$ 122,000

Engage Grant,
Design and prototyping of an ingestible capsule for biomedical applications
Srikar Vengallatore. Supporting organization: Micropharma, Inc.
$24,750

CREATE
Training Program in Neuroengineering
Bruce Lennox (PI), Barrett, C.; Costantino, S.; Grutter, P.; Juncker, *P.I.* Bruce Lennox *Co-Applicants:* Barrett, C.; Costantino, S.; Grutter, P.; Juncker, D.; Kirk, A.G.; Mauzeroll, J., Wiseman, P.; Colman, D.
$ 1,750,500 (2011-17, 6 years)

CREATE
Training Program in NanoBioMachines
Kalle Gehring (PI) and 9 others
$ 1,800,000 (2011-2017, 6 years)

NSERC/CIHR

CHRP
Rapid detection of MRSA and identification of strain using an autonomous microfluidic chip with bacteriophages.
D. Juncker (PI), Zourob, M; Lebel, P;
$ 516,500 (2011-13)

FQRNT

Majorana Fermions in Semiconductor Heterostructures,
Team Grant,
Guillaume Gervais (PI) with Szkopek and Mi.
$205,248 (2011-13)

Sonic Black Hole in the Laboratory,
Team Grant
G. Holder (PI), G. Gervais and A. Maloney.
$206,000 (2011-2013)

Nanotechnology□based platform for Epigenetic Mapping
Team Grant,
Walter Reisner (PI) with Moshe Szyf and Andreas Ruediger,
$183,000 (2011-13)

Inexpensive, high-efficiency solar cells,
Team Grant
Nate Quirianio
$ 159,000 (2011-13)

INstitut TRansdisciplinaire d'Informatique Quantique (INTRIQ)
Regroupement Startegique
Alain Tapp (PI) and 20 others
$150,000

Varia :

Micro and Nanobioengineering
Canada Research Chair II,
David Juncker
$ 125,000 (2011-16, 5 years)

Projet McGill-Pisa sur le developpement de l'electronique quantique non-abelienne
MDEIE PSR,
Guillaume Gervais
$150,000 (2011-2014)

McGill-India Nanotechnology Program,
Integrating nanoscale materials, structures and devices with microsystems
S. Vengallatore (PI) and R. Rao
$20,000

Studying Interactions in One-dimensional Electronic Systems.
Research contract with Sandia National Laboratories, USA
Guillaume Gervais
$39,110 (USD)

Design of biointerface with enhanced sensitivity and specificity for Lab-on a-Chip devices.
France Canada Research Fund,
Maryam Tabrizian
$10,000 (2011-2013)

Nanoelectronics and Quantum Materials, Concordia University Research Chair (Tier II),
Alexandre Champagne
$15,000 / year (2012-2017)

Electro-optics of quantum nano-electromechanical systems (NEMS), Concordia Seed Funding (Team)
Alexandre Champagne
$12,750

Concordia University Research Award (Emerging),
Alexandre Champagne
$5,000 (2011-2012)

Développement d'outils pour les études hémo-microdynamique
University of Ottawa,
Marianne Fenech
$11,000