|QSciTech⟩

NSERC CRSNG

CREATE training program
Programme de formation FONCER

Bridging the gap between quantum science and quantum technologies

– *Training the next generation of quantum scientists, engineers and entrepreneurs*

to develop quantum technologies in Canada, sustain its industry, and prepare our graduate students for high impact strategic jobs

Added-value training for

- ***Business creation***
- ***Intensifying industrial research in quantum technologies***
- ***Development of new products exploiting quantum effects***
- ***A new business intelligence for commercializing quantum technologies***

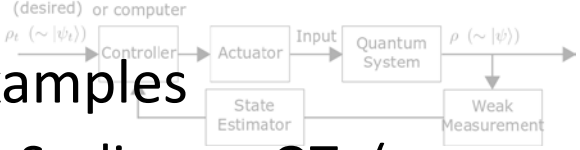
Applicants *Y. Bérubé-Lauzière (U. de Sherbrooke - UdeS),* L. Childress (McGill), A. Blais (UdeS), C. Allen (Laval), E. Dupont-Ferrier (UdeS), S. Simmons (SFU), A. Champagne (Concordia), J. Sylvestre (UdeS), S. Francoeur (Polytechnique), M. Côté (U. de Montréal), P. Fournier (UdeS)

INSTITUT QUANTIQUE
UNIVERSITÉ DE SHERBROOKE
McGill
UNIVERSITÉ LAVAL
SFU SIMON FRASER UNIVERSITY ENGAGING THE WORLD
UNIVERSITÉ Concordia UNIVERSITY
POLYTECHNIQUE MONTRÉAL
Université de Montréal

Rationale

- Deploying quantum technologies (QTs) in real-world applications requires quantum science (of course!), but also engineering methods and solutions to
  - increase uniformity, yield, and reliability

  … and business skills, to
  - ensure economic and societal impact

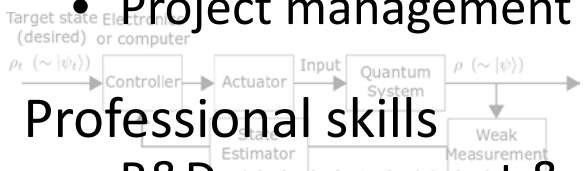


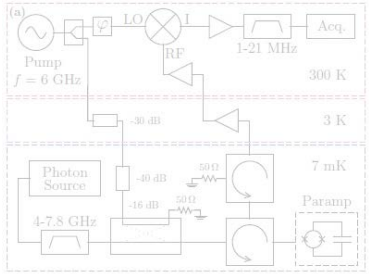
Examples
- Scaling up QTs (e.g. quantum computer)
- Integrating quantum materials and devices into complete systems (e.g. quantum refrigeration)
- QTs require interfacing with advanced conventional technology for operation (e.g. quantum sensing)

Purpose of the QSciTech program

Provide practical collaborative training to graduate students in physics and engineering, but also in comp. sci. and math, giving them a view of the whole chain needed for QT development encompassing:

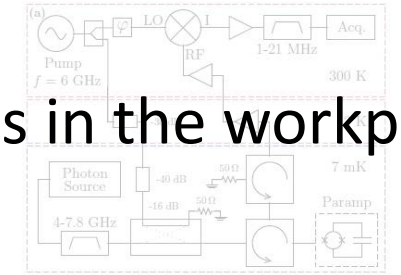
- Fundamental quantum science
- Engineering methods
  - Design
  - Project management
- Professional skills
  - R&D management & decision making
  - Entrepreneurship
  - Innovation
  - Communications and team work
  - Intellectual property (IP)
  - Commercialization

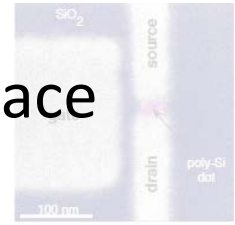




Objectives

1. Provide common background and langage necessary for communicating effectively to develop QTs
   - Engineering-aware physicists (and scientists) and quantum-aware engineers (and scientists)
2. Develop professional skills necessary to the QT industry
   - Business-awareness/intelligence focused on QT
   - Engineering design and project management
3. Develop teamwork abilities in concrete problem-solving situations integrating quantum science, engineering and professional skills
4. Provide opportunity to exercise skills in the workplace and prepare for employment in QTs
5. Promote enrollment of women in QT



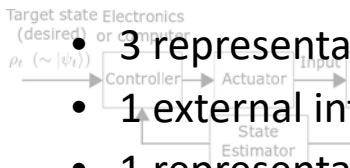


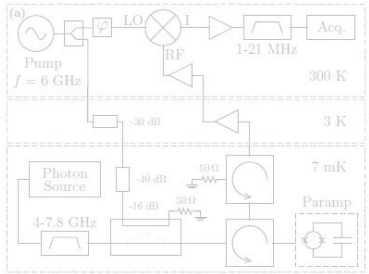
Representatives

- Coapplicants (* = representatives in participating universities)
  - Yves Bérubé-Lauzière* (PI, Prog. Director, U. de Sherbrooke - UdeS)
  - Lilian Childress* (McGill U.)
  - Alexandre Blais (UdeS)
  - Claudine Allen* (U. Laval),
  - Eva Dupont-Ferrier (UdeS)
  - Stephanie Simmons* (Simon Fraser U.)
  - Alexandre Champagne* (Concordia U.)
  - Julien Sylvestre (UdeS)
  - Sébastien Francoeur* (Polytechnique)
  - Michel Côté* (U. de Montréal)
  - P. Fournier (UdeS)
- **Program Coordinator**
  - **Marc Leclair**

Management structure (1/2)

- Program committee (PC)
  - Guides the strategic direction of the program
  - Oversees program progress and future directions
  - PC Chair approves each year's progress report (1st progress report at end of 2nd year)
  - Composed of
    - 2 Vice-President or Vice-Dean Research from one of the partner universities
    - 3 representatives from industry
    - 1 external int'l researcher
    - 1 representative from business
    - 1 representative from equity
    - 1 grad trainee
    - Program Director as a non-voting member
  - Meets once to twice a year



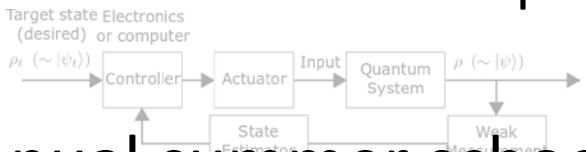


Management structure (2/2)

- Management committee (MC)
  - Responsible for implementation and operation of the program
  - Writes yearly reports
  - Selects trainees, approves internships, coordinates between universities
  - Reviews trainees and and employers internship reports
  - Organizes annual general assembly at Summer School to collect feedback
  - Composed of
    - Program Director as Chair (Yves Bérubé-Lauzière)
    - 1 academic from each partner university
    - 2 industry representatives
    - a member from professional skills training (CUEFR at UdeS)
    - a supervisor from UdeS COOP services
  - Program Director chairs the MC throughout existence of the program
  - Members elected for 2 years with 1 year extension for half initial members
  - Coordinator takes part to all meetings
  - Meets at least twice a year
- Students committee (SC)
  - Provides feedback to the MC and PC
  - Participates in organizing the Summer School and in outreach activities

Structure of training program

- 3 training phases
  - Phase 1 - Multidisciplinary Training – during a 1st term
  - Phase 2 - Interdisciplinary Teamwork – during a 2nd term
  - Phase 3 – Internship – during a 3rd term
- Annual summer school



Phase 1 – Multidisciplinary Training

- **Engineers & computer scientists** take Course 1A - Quantum Mechanics for Engineers at UdeS or an equivalent in their university
- **Physicists** take Course 1B - Engineering Design and R&D Project Management at UdeS or an equivalent in their university (3 credits)
- **All students** take Essential Professional Skills courses:
  - Course 1C - R&D and Entrepreneurship at UdeS (five 6-hour workshops during a term) or equivalent in their university or from Mitacs (3 credits)
  - Course 1D - IP & Innovation at UdeS (five 6-hour workshops during a term) or equivalent in their university or from Mitacs (3 credits)

* All courses at UdeS can be taken remotely by teleconf

Phase 2 – Interdisciplinary teamwork

- **All students** take the problem-based learning (PBL) Course 2 - From Quantum Science to Quantum Technologies & Industry at UdeS* (3 credit)
  - **Backbone course of the program**
  - All students (physicists, engineers, comp. sci., math) brought together
  - Students work in interdisciplinary teams of 4 on one or two specific quantum technologie(s) of their choice, applying skills acquired in Phase 1
  - Phase 1 courses mandatory as prerequisites

* Course will be available remotely by teleconf

QSciTech course recognition

- QSciTech activities will integrate best in a student's academic curriculum if some of them are considered as part of the student's academic program
- Some departments may consider some of the courses taken by their trainee in the QSciTech CREATE program as part of the trainee's' academic program
  - This is encouraged, as this will reduce the burden of the QSciTech program atop the graduate program in which the student is enrolled
  - … but there is no obligation to do so, QSciTech does not want to be intrusive; each department has its own policies in terms of the courses to be taken by its students; it will most likely not be possible for a department to recognize all courses taken in the QSciTech program because that would take too much of the credits the student need to take in their own department.
  - Examples:
    - At the Faculty of Engineering at Université de Sherbrooke (UdeS), a Master's student must take 5 graduate technical courses and the Faculty will recognize courses 1A and 2 for a total of 6 credits as part of the student's academic curriculum.
    - In the Physics Department at UdeS, a Master's student must do 3 graduate physics courses (total of 9 credits), and the department will recognize Course 1B (3 credits) from the QSciTech program as part of the student's mandatory 3 courses. QSciTech does not want to interfere with departmental policies, as the purpose of CREATE programs is to provide added value to regular programs.
- Planned that trainees will get formal recognition for QSciTech training through an official QT microprogram certificate (work in progress)

Phase 3: Internships in industry*

* A stay in a university research lab (e.g. of a professor's collaborator's lab) is not eligible

- Industrial and institutional partners for internships
  - D-Wave (Burnaby, BC)
  - Anyon Systems Inc (Montréal, QC)
  - 1QBit (Vancouver, BC)
  - IBM Canada (Bromont, QC
  - Microsoft (Redmond, WA)
  - Rigetti (Berkeley, CA)
  - SB Technologies Inc. (Sherbrooke, QC)
  - STMicroelectronics (Grenoble, FRANCE)
  - Keysight Technologies Canada Inc. (formerly Agilent and HP)
  - Defence R&D Canada – DRDC (Ottawa, ON)

  This is an initial list, we will work on increasing the number of partners

- Internships will also be possible in a company that a student finds by herself/himself with a project in quantum technology
- UdeS' COOP services will coordinate and supervise the internships
- Internships will be funded through MITACS (see later) with some exceptions possible for non-MITACS fundable internships

Summer school

- Held annualy over 4 days
- Mandatory for QSciTech-funded students (all fees paid)
- Activities
  - Further professional skills training (1/2 to 1 day)
  - Social issues in science and technology (S&T) (1/2 to 1 day)
    - Gender diversity, its effects on creativity-innovation-business-governance, ethics, future impacts of QTs on society, historical perspectives and precursors to QTs, the psychology of discovery and creativity in S&T…
  - Specialized technical topics of current interest to the industry (1 day)
  - Short pitch student presentations of research projects (1/2 day)
  - Student presentations on hot topics in quantum technologies (1 day)

Student eligibility and selection

- Eligibility for getting QSciTech student funding
  - Any M.Sc./Ph.D. student from a participating university (students from non-participating universities not eligible)
- Selection process of students to be funded
  - Student submits to Coordinator:
    - Training profile (1-page letter with motivations and goals for receiving QSciTech training, a CV, and note transcripts)
    - QSciTech application form
  - Profile evaluated by Management Committee

  Selection criteria:
    - experience and adequacy of the student's graduate research project with QSciTech themes and industrial partners
    - excellence of academic record, and research record for Ph.D.s

  Interviews may be conducted with candidates

Student eligibility, particular cases

- Postdocs: admissible, 3k$/year available for 1 postdoc, no internship
- Scholarship holders (NSERC, provincial funding, university funding): admissible, but no QSciTech funding, however internship salary possible
  - some particular cases of scholarship holders may have to be evaluated on a case-by-case basis
- Courses opened to all students even if not enrolled in QSciTech (registration fees may apply if course part of student regular academic curriculum), no limit on number of participating students, but funding available for a limited number of students
  - Phase 1 courses prerequisite to Phase 2 course

Structure of funding

Table 2: Evolution of trainee numbers and stipends.

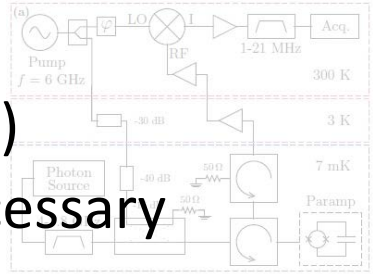
Trainees	Year / Activities	1 nb	1 amount	2 nb	2 amount	3 nb	3 amount	4 nb	4 amount	5 nb	5 amount	6 nb	6 amount	7 nb	7 amount	Total End Stipends nb	Total End Stipends amount
BSc's		3	$13 500	4	$18 000	4	$18 000	4	$18 000	4	$18 000	4	$18 000			23	$103 500
MSc's	Train./Stipend	4	$48 000	7	$84 000	7	$84 000	7	$84 000	7	$84 000	7	$84 000			39	$468 000
	Internship			4		7		7		7		7		7			
PhD's	Train./Stipend	6	$90 000	7	$105 000	7	$105 000	7	$105 000	7	$105 000	7	$105 000			41	$615 000
	Train./Stipend			6	$60 000	7	$70 000	7	$70 000	7	$70 000	7	$70 000	7	$70 000		$410 000
	Internship																
Postdocs		0		1	$3 000	1	$3 000	1	$3 000	1	$3 000	1	$3 000			5	$15 000
Tot.involv'd		13		29		33		33		33		33				80 graduating	
	Totals:		$151 500		$270 000		$280 000		$280 000		$280 000		$280 000		$70 000		**$1 611 500**
Funding received from NSERC:			**$175 000**		**$275 000**		**$300 000**		**$300 000**		**$300 000**		**$300 000**				**$1 650 000**

Nominal student funding from QSciTech

- Ph.D.: 5k$/term for 5 terms + 15k$ max (Mitacs) for internship, Total = 40k$
  Assuming 20k$/year for 3 years = 60k$
  → there remains 20k$ to be paid by supervisor **(training supports research!)**
- M.Sc.: 4k$/term for 3 terms + 15k$ max (Mitacs) for internship, Total = 27k$
  Assuming 18k$/year for 2 years = 36k$
  → there remains 9k$ to be paid by supervisor
- Support for 4 (3 the 1st year) senior B.Sc. internships/year in our research labs for promoting recruitment (4.5k$/scholarship)

Other support

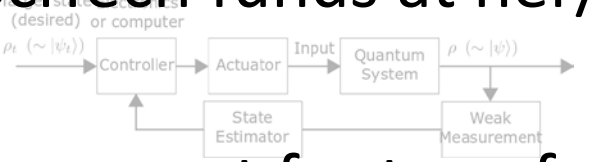
- International Exchanges
  - Support on a competitive basis three 4-month international exchanges/year for PhD trainees to allow them acquiring a broader set of scientific/technical skills in areas where we have less expertise (4k$/exchange)
  - Opportunities for our trainees for scientific stays in international labs, thus expanding their own network. Funding from MITACS' Globalink Research Award program or other sources (*e.g.* Canada-France exchange programs, Japan scholarships, …) will be applied for.
- QSciTech events
  - summer school (travel, lodging, meals)
  - travel to some QSciTech courses if necessary



Fund transfers

- Fund transfers for each student made through interuniversity agreements (as per NSERC rules) for fractioned installments (see next slide)

- Funds transferred to the coapplicant at the student's university; coapplicant manages all QSciTech funds at her/his university



- Agreement for transfer of 25k$ for a Ph.D., 12k$ for an M.Sc. (these are max amounts that depend on the contribution of the student's university to QSciTech and the use of that contribution thus far)

Installments schedule and conditions

- First installment (Ph.D.: 5k$, M.Sc. 4k$) transferred to the student's university at the beginning of the term Phase 1 activities are undertaken. If the student does not do the activities, funds will be transferred back to QSciTech.

- Second installment (Ph.D.: 5k$, M.Sc. 4k$) transferred once student undertakes Phase 2 activities and Coordinator receives proof of success of Phase 1.

- As soon as Phases 1 and 2 activities are completed and Coordinator receives proof of success of Phase 2, the rest of the NSERC funding for the student (Ph.D.: 15k$, M.Sc.: 4k$) is transferred. Student then ready for Phase 3 - internship, for which the student will receive MITACS funding as per MITACS regulations (QSciTech students will typically receive 12 to 15k$ for an internship).

Internship salary

- Exact amount received by student will depend on the nature of the internship and the agreement between the student, her/his supervisor and the internship host
- MITACS supported internships
  - Overall budget for an internship: 15k$ (7.5k$ from MITACS and 7.5k$ from employer)
  - As per MITACS rules sometimes up to 5k$ of that budget can be used for consumables and support needed for work during the internship
  - QSciTech does not intervene in the administrative aspects of MITACS funds as these are directly sent to student's university
  - internships will have the same structure as COOP undergraduate internships: the QSciTech trainee works for his host, thus intellectual property (IP) will belong to the host, unless trainee works on a collaborative project between the host and his supervisor (trainee's university and the host then negotiate the IP as usual).

Planning

Table 2: Evolution of trainee numbers and stipends.

Trainees	Year / Activities	1 nb	1 amount	2 nb	2 amount	3 nb	3 amount	4 nb	4 amount	5 nb	5 amount	6 nb	6 amount	7 nb	7 amount	Total End Stipends nb	Total End Stipends amount
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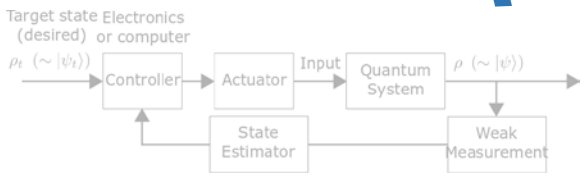
- Program start: January 2019
- 1st year serves to put the program into place
- To ease program set-up:
  - only coapplicants and PI will enroll students on the 1st year (10 students hired in 1st year, 14 in subsequent years, see table)
  - … but it may be that students from other professors will get enrolled if one of the coapplicant is not ready to hire (we will know that very soon)

Measures of success

- Measures of success are deliverables to NSERC who will use them to evaluate the program
  1. Number of applicants (by gender)
  2. Number of trainees accepted (by gender)
  3. Successful completion by trainees of all training activities (target >95%)
  4. Percentage of women participating in the program and evolution of that percentage (target 30% at program's end, which is ambitious given our fields and as the typical percentage of women in science and engineering is ~20%)
  5. Time to graduation
  6. Trainee employment in the QT industry after graduation (we aim at a 90% placement rate)
  7. Number of new academia-industry collaborations emerging from QSciTech and associated grants (we aim at an increase in that case)
  8. Number of publications of our trainees (to ensure scientific quality)
  9. Number of industrial partners. This will grow with the reputation of the program, the number of companies, and with our efforts seeking for new partners
  10. Cash sponsorship of industrial partners

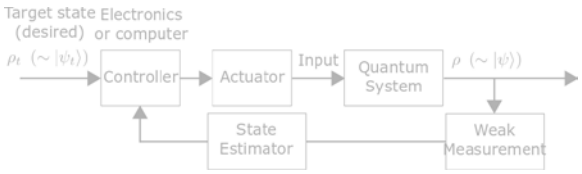
Thank you for your attention!

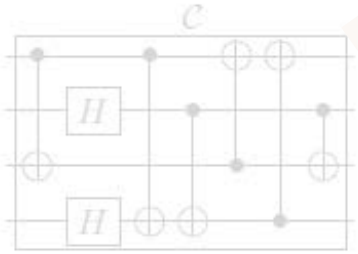
Questions?

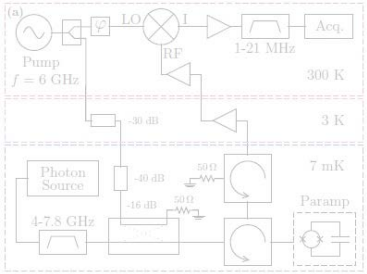


Yves.Berube-Lauziere@USherbrooke

Supplementary slides







Summer school (more details)

- **Held annualy over 4 days**
- **Mandatory for QSciTech-funded students (all fees paid)**
- **Activities**
  - **Further professional skills training (1/2 to 1 day)**
    - Tutorials on specialized skills not covered in the core of QSciTech, e.g. the structure of venture capital and funding for start-ups, strategies to better present QTs and research in the media, etc. Tutorials will incorporate case studies and on-site real-time assignments to promote interactivity. Trainees will be consulted to select topics.
  - **Social issues in science and technology (S&T) (1/2 to 1 day)**
    - Gender diversity, its effects on creativity-innovation-business-governance, ethics, future impacts of QTs on society, historical perspectives and precursors to QTs, the psychology of discovery and creativity in S&T...
  - **Specialized technical topics of current interest to the industry (1 day)**
    - Topics selected jointly with our industrial collaborators according to their specific interests. Tutorials in these topics will be given by invited specialists. Examples are eXtreme programming methodologies, radio-frequency engineering, finite element modelling, emphasis will be on providing intuition and an overview of these topics, why they are useful in themselves and in relationship with QTs, pointers to best entry-level literature.
  - **Short pitch presentations of research projects (1/2 day)**
    - All trainees will present their research in the form of a 3-minute pitch to get funding (prizes for best presentations). Similar to the Three Minute Thesis (3MT) competition. This will encourage communication and outreach skills, and prepare students to participate to the various 3MT competitions, which are a great forum for promoting QTs.
  - **Hot topics in quantum technologies (1 day)**
    - Very recent research in QT (past year or two), or research foreseen to have a significant impact in the near future, will be reviewed in 30-45 minute talks given by students, followed by a discussion session. The presentations will need to provide intro-ductory background, survey the main issues for non-specialists, and give an overview of work at the current frontier, ending with an editorial view by the presenter leading to the discussion.

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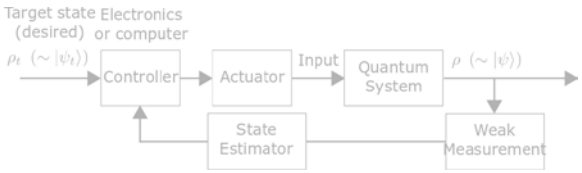
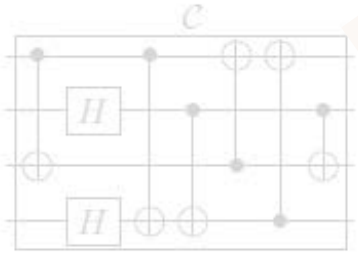

Target state (desired)
Electronics or computer
Controller
Actuator
Input
Quantum System
State Estimator
Weak Measurement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AFM
SL

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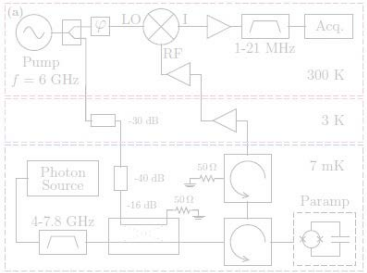

Pump
f = 6 GHz
LO
RF
I
Acq.
1-21 MHz
300 K
3 K
7 mK
Photon Source
4-7.8 GHz
Paramp

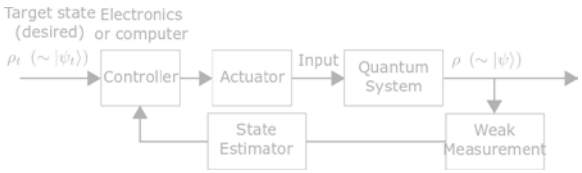
SiO2
source
gate
drain
poly-Si dot
100 nm

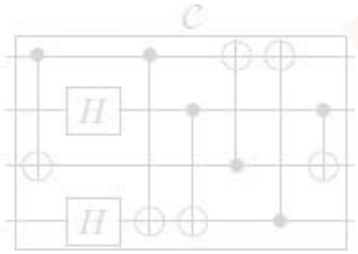
JPA
Central JJ

5 nm

k′λ′τ
kλτ

X
Z

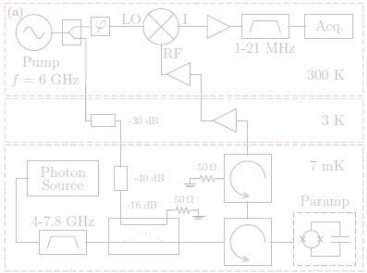

Target state (desired)
Electronics or computer
Controller
Actuator
Input
Quantum System
State Estimator
Weak Measurement


H
H

|R⟩
|L⟩

AFM
SL

p = −0.89
−0.41
0.02
0.36
0.83


Pump
f = 6 GHz
LO
RF
I
Acq.
1-21 MHz
300 K
3 K
7 mK
Photon Source
4-7.8 GHz
Paramp

SiO2
source
gate
drain
poly-Si dot
100 nm