AT A GLANCE
Founded: 1987
Most recent renewal: 2012
Program Director: Louis Taillefer, Université de Sherbrooke
Fellows and advisors: 64
Institutions represented: 31, in 7 countries
Fields and subfields: condensed matter and quantum physics; atomic, chemical and computational physics; nanomaterials and materials engineering
Interaction meetings: 2; in Montreal and Toronto, Canada
Relevant knowledge users: industry (e.g., quantum computing, power transmission, transportation, magnetic medical imaging, wireless communications)
Partner: Gordon & Betty Moore Foundation

QUANTUM MATERIALS

Invents and explores materials whose novel and unusual electronic properties, like superconductivity, could revolutionize technology.

The program in Quantum Materials experienced a year marked by significant research advances and expanded engagement with key research communities. During two interaction meetings, fellows discussed several key topics related to the program's themes, including cold atomic gases, high-temperature superconductivity, spin liquids and topological materials.

The program engaged in extensive international partnership activities, including the continuation of a joint venture with the Gordon and Betty Moore Foundation's EPiQS initiative. Through this relationship, EPiQS-supported researchers and their trainees participated in the program's meetings and annual summer school. In addition, the program established intellectual synergy with France's quantum materials community, integrating leading researchers from the country into its meetings. The program will engage an expanded network of French quantum researchers by holding a meeting at the Collège de France in Paris next year. The program also had notable interaction with the Japanese quantum materials community. CIFAR fellows **Yoshi Maeno** (Kyoto University), **Yoichi Ando** (University of Cologne) and CIFAR Advisor **Hide Takagi** (Max Planck Institute for Solid State Research) belong to a multi-institutional Japanese research team that was awarded a grant for their proposed 'Topological Materials Science (TMS)' project through Japan's MEXT. This grant has led to the creation of a 'TOPO-Q' network and has enabled TMS researchers to engage with CIFAR's Quantum Materials program.

The long-standing convening and collaborative power of the program was evident this year via the results of the inaugural Canada First Research Excellence Fund (CFREF) competition. Of the 42 proposals put forward, two quantum physics proposals from the Université de Sherbrooke (UdeS) and the University of British Columbia (UBC) were among the five CFREFs awarded, resulting in a $100 million investment by the Government of Canada in this research area. Notably, CIFAR fellows **Alexandre Blais**, **Patrick Fournier**, **Louis Taillefer** and **André-Marie Tremblay** (UdeS), and **Andrea Damascelli**, **Ian Affleck**, **Doug Bonn**, **Joshua Folk**, **Marcel Franz** and **George Sawatzky** (UBC) led and developed these proposals. CIFAR is recognized as contributing to the proposals' success by raising the profile of Canadian quantum research and establishing a strong, trusted and sustained platform of dialogue, synergy, idea-generation and collaboration among the world's top quantum researchers through its quantum programs.

Research

- Fellows **Louis Taillefer** (Université de Sherbrooke), **Cyril Proust** (LNCMI, France), **Doug Bonn**, **Ruixing Liang** and **Walter Hardy** (all University of British Columbia), along with other collaborators, identified a quantum phase transition in copper-oxides that is associated with the termination of the 'pseudogap.' This landmark discovery was found to result in a dramatic reduction of superconductivity in cuprates.
  > Badoux S, Tabis W, Laliberté F, Grissonnanche G, Vignolle B, Vignolles D, Béard J, **Bonn DA**, **Hardy WN**, **Liang R**, Doiron-Leyraud N, **Taillefer L**, **Proust C**. 2016. Change of carrier density at the pseudogap critical point of a cuprate superconductor. Nature. 531: 210-214.

- Using nuclear magnetic resonance, Senior Fellow **Takashi Imai** (McMaster University) and collaborators presented the first experimental evidence of a 'spin-liquid' state of matter at near absolute zero temperature in the quantum material herbertsmithite. This was the first experimental evidence that a spin liquid state of matter exists. The finding may advance a new field of study and contribute to the understanding of other states like superconductivity.

- A collaborative effort between Associate Fellows **Ian Fisher** and **Steve Kivelson** (both Stanford University) resulted in a study that provides evidence for the presence of a nematic quantum critical point in optimally doped iron-based superconductors and suggests a potential role of nematicity in enhancing superconductivity.
  > Kuo HH, Chu JH, Palmstrom JC, **Kivelson SA**, **Fisher IR**. 2016. Ubiquitous signatures of nematic quantum criticality in optimally doped Fe-based superconductors. Science. 352(6288): 958-962.

Other notable publication

- Achkar AJ, Zwiebler M, McMahon C, He F, Sutarto R, Djianto I, Hao Z, **Gingras MJP**, Hücker M, Gu GD, Revcolevschi A, Zhang H, Kim YJ, Geck J, **Hawthorn DG**. 2016. Nematicity in stripe-ordered cuprates probed via resonant x-ray scattering. Science. 351(6273): 576-578.

IdeasExchange

- Early conversations took place between program fellows and industrial representatives involved in wind turbine manufacturing. The discussions focused on uncovering potential applications of cuprate superconductors.

- A private event at the Centre des sciences de Montréal highlighted the recent discovery of the quantum phase transition made by CIFAR fellows.

Global Academy

- The program committed significant efforts in 2015/2016 toward training the next generation of quantum materials leaders. The program held its annual summer school in Toronto, Canada attracting over 70 participants. The agenda was developed by a group of trainees supervised by CIFAR fellows and included research lectures, interactive poster sessions, career development sessions and significant informal interaction time. Summer school participants were also invited to attend the program meeting held immediately afterward, extending their opportunity to interact with program fellows and explore research themes for future collaborative and/or training endeavours.

To learn more: **https://www.cifar.ca/research/quantum-materials/**

Associate Fellow Subir Sachev, Program Director Louis Taillefer and Program Reporter Nicolas Doiron-Leyraud in discussion at the October 2015 meeting of CIFAR's program in Quantum Materials.