Researchers find evidence of 'quantum critical point' in high temperature superconductivity material

June 22 2012, by Bob Yirka

(Phys.org) -- In the seemingly never ending search for a superconductor that can operate at or near room temperature, researchers have discovered a lot of things about superconductors in general. One of these is that there appears to be two classes of them - those materials that only take on their superconductive properties when exposed to an environment just a few degrees above absolute zero, and those that do the same at somewhat higher temperatures. Those in the latter group are said to have high critical-temperature superconductivity (T_c). Unfortunately, researchers have made little progress in understanding how such materials are able to do what they do. Now, new research by a team of Japanese, British and American researchers has found that at least one of these T_c materials likely has a quantum critical point (QCP), which if true, would go a long way towards explaining why some materials are able to become superconductors at higher temperatures than others. They have published a paper detailing their findings in the journal *Science*.

A material's QCP is analogous to the phase changes in ordinary materials, such as ice melting to water. In the quantum world, rather than occurring due to the ordering of atoms, they are based on electronic carriers, and come about as a result of interactions rather than organization. At the QCP, the properties of the material change suddenly, due to quantum fluctuations. Researchers have suspected that the reason materials with T_c are able to become super conductive (have no resistance to an electrical charge) is because they have a QCP, but thus far have not been able to prove it.

In this new research, the team has come close. They worked with a T_c known as an iron pnictide, because of its location on the periodic table; in this case it was arsenic. To test the material for a QCP, the team first added a doping factor to provide an extra charge. When put in an extremely cold environment and adding just the right amount of the doping factor, the material becomes a superconductor.

To test the material to see if it had a QCP, the team turned to a measurement method known as the *London penetration depth*, which measures the depth to which a magnetic field penetrates a given material. In so doing, the team was able to see a very noticeable jump in the penetration depth with their sample as the doping factor was tweaked to its optimal value.

Unfortunately, while the jump is a good sign that the T_c sample does likely have a QCP, it's not definitive proof, though it does come close. Close enough that it gives researchers a renewed belief that their theoretical models have been correct all along, likely leading to new research that might just uncover some other mysteries still surrounding super conducting materials.

More information: A Sharp Peak of the Zero-Temperature Penetration Depth at Optimal Composition in BaFe2(As1–xPx)2, *Science* 22 June 2012: Vol. 336 no. 6088 pp. 1554-1557 DOI: 10.1126/science.1219821

ABSTRACT
In a superconductor, the ratio of the carrier density, n, to its effective mass, m*, is a fundamental property directly reflecting the length scale of the superfluid flow, the London penetration depth, λL. In two-

dimensional systems, this ratio n/m^* ($\sim 1/\lambda_L^2$) determines the effective Fermi temperature, T_F. We report a sharp peak in the x-dependence of λ_L at zero temperature in clean samples of $BaFe_2(As_{1-x}P_x)_2$ at the optimum composition x = 0.30, where the superconducting transition temperature T_c reaches a maximum of 30 kelvin. This structure may arise from quantum fluctuations associated with a quantum critical point. The ratio of T_c/T_F at x = 0.30 is enhanced, implying a possible crossover toward the Bose-Einstein condensate limit driven by quantum criticality.

Citation: Researchers find evidence of 'quantum critical point' in high temperature superconductivity material (2012, June 22) retrieved 3 May 2024 from https://phys.org/news/2012-06-evidence-quantum-critical-high-temperature.html