Title: 10 Minutes of the Aharonov-Bohm effect and 20 minutes of a new superconducting gravitational-wave detector

Date: Jun 22, 2016 02:00 PM

URL: http://pirsa.org/16060056

Abstract:

Part 1. A new concept for a GW detector

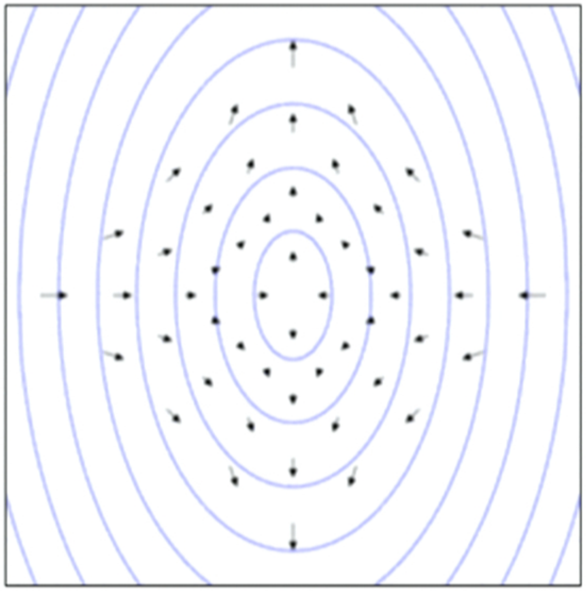
Armen Gulian, Joe Foreman, Shmuel Nussinov, Vahan Nikoghosyan, Lou Sica and Jeff Tollaksen
(Chapman University)

- We are intended to demonstrate that compared with LIGO, orders of magnitude smaller size together with orders of magnitude higher sensitivity may be achieved.
- Concept is based on traditional laws of physics (Einstein, Maxwell, and Newton equations - nothing exotic).

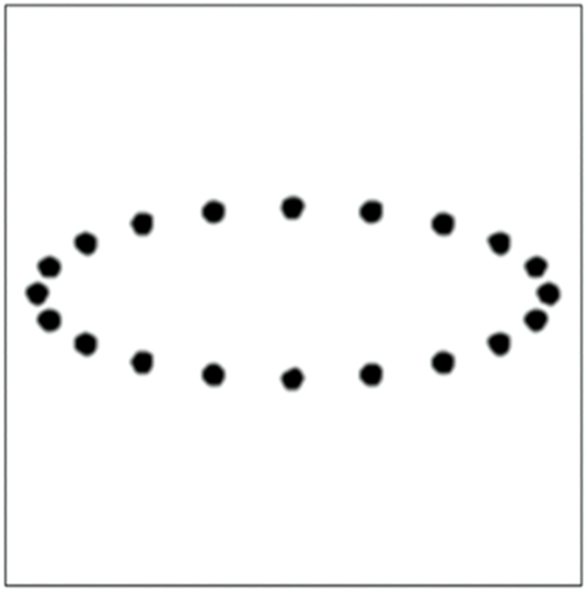
1

Physical action of GW

Field Lines of GW

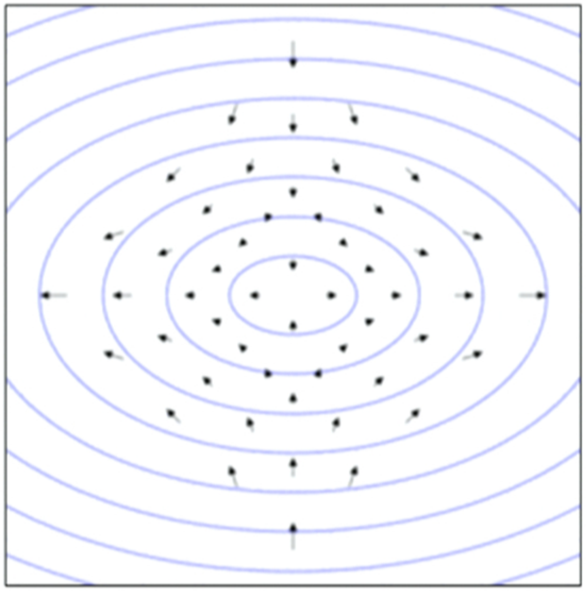


Driving Test Particles

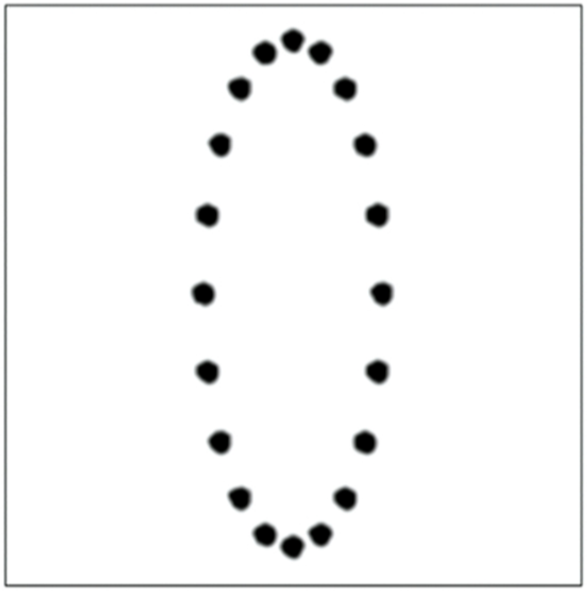


Physical action of GW

Field Lines of GW

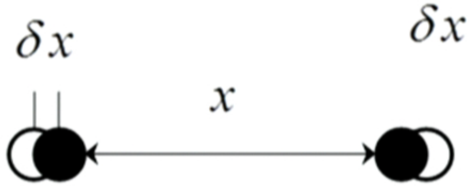


Driving Test Particles



Physical action of GW

Two Particles in GW



$\delta x \sim xh$ - simple but horrible relation:

$h(t) = h_0 \cos(\omega t), \quad h_0 \leq 10^{-21}$

$\delta x (at\ x \sim 1km - LIGO) \sim 10^{-18} - 10^{-23}\, m$

$angle: \alpha = \delta x / x \sim h \sim 10^{-21} - 10^{-26}$ - explains why LIGO is big

distance to Moon: 400,000km=4x10^8m

$accuracy \quad \delta x \sim x \cdot h \sim 10^{-8} - 10^{-13}\, of\ \ human \quad hair$

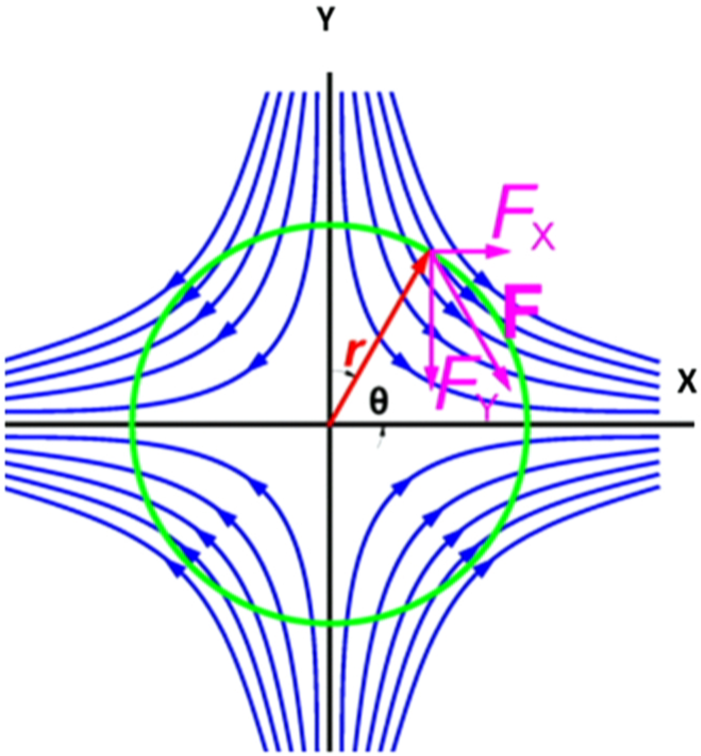
One human hair angular resolution is by far not enough !!!

How to do better than LIGO

- Fight small values of h_0 not by large spatial arms but rather with large number of charge carriers : 10^{30} m^{-3} electrons in metals.
- Eliminate fundamental shot (Poisson) noise of photons by using Bose-condensates. Superconductors deal with Cooper condensates – relatives of Bose-condensates, very low noise, and high coherence (infinitely long coherence time).
- If sizes are small - spatial reorientation is possible.
- LIGO achievements still can be utilized (like vibrational noise isolation (10^{-10}), bandwidth filtering, etc.).
- Neutralize Moon, Sun, etc.
- Don't fight Coulomb interaction!

4

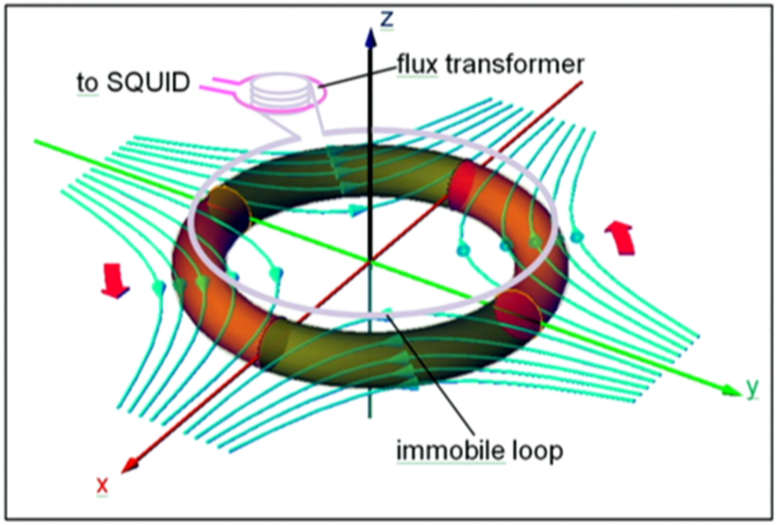
Action of GW on a circular loop of particles

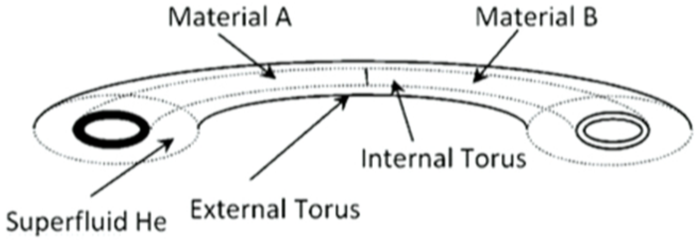


- The GW force lines are shown in blue (the center of circular body mass is at (x=y=0).
- Everywhere on circle, |**F**| is constant.
- Force **F** at a given point ***r*** of the circle is tangential to the field line crossing or touching the circle at that point.
- Decomposing **F** into F_x and F_y allows calculation of the torque: τ=**r**x**F** on the circle.
- In each of the quadrants the integral torque is non-zero.
- For a uniform mass distribution the total torque vanishes. However, it does not vanish for a quadrupolar mass distribution on the circle, so the circle will rotate.

The field-lines reverse their direction each period and the oscillating torque generates rotational oscillation of the quadrupolar circular body.

Detector schematics





"helium submarine"

$$n \sim 10^{30} m^{-3}$$
$$\omega h_0 \sim 10^{-24} s^{-1}, \quad h_0 \sim 10^{-26}$$
$$r s_{eff} \sim 10^{-1} m^3$$
$$I(t) \approx 0.4\, femtoA \cdot \sin(\omega t)$$

$$\tau_z^{total}(t) = (M_B - M_A)\,\omega^2 h_0 r^2 \cos(\omega t)/4$$

$I\ (t) = e n r \omega h_0 s_{eff} \sin(\omega t)/4$ **- if Cooper pairs in torus stay still**

Magnetic field moves them, so the pick up loop is required.

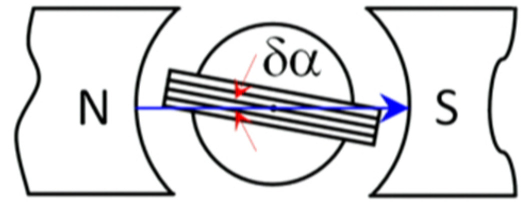
On agenda:

More strict calculations and experimental verification.

6

Signal acquisition

There are a variety of approaches for high-efficiency (>90%) conversion of rotational motion to an electrical signal. A galvanometric approach is one of them: $\Phi = \vec{B} \cdot \vec{S} = |B||S|\cos\alpha$,



$$\delta\Phi = \frac{d\Phi}{d\alpha}\delta\alpha = |B||S|\sin\alpha\ \delta\alpha.$$

Can WM help?

If $B \sim 10$ Tesla (SC coil), $S \sim 10^2$m^2, $\alpha = 90^0$, $\delta\alpha \sim h_0 \sim 10^{-26}$

Then $\delta\Phi \sim 10^{-23}$Weber$\sim 10^{-8}\Phi_0$. (Φ_0 - flux quantum)

Single SQUID sensitivity$\sim 10^{-6}\Phi_0$Hz$^{-1/2}$. In 10^4 sec detects $10^{-8}\Phi_0$ or 10^4 SQUIDS in 1 sec!

Proposal to NSF for evaluation of noise, comprehensive calculation of signal/noise, and detailing overall design.

Ultrasensitive detectors of objects via their gravity

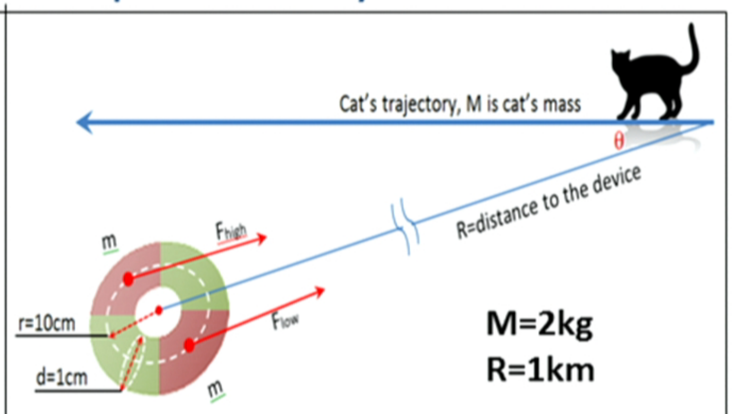
Chapman University

OBJECTIVE

Verify the concept underlying the proposed detectors by calculations and experiments.

EXPECTED RESULTS/BENEFITS

If successful, our work will lead to development of novel instruments that will allow detection of objects even if they are deeply underground, or obscured by clouds, buildings, etc., which generally cannot be be detected using other means. The method can be implemented either terrestrially or from orbiting satellites with obvious improvement of intelligence capabilities.



PERFORMANCE METRICS

	SOA	Advancement
Metric 1	Strain sensitivity to gravitational fields	From 10^{-22} to 10^{-27}
Metric 2	Mass of and distance to the gravitationally detected object	From about 1 Ton at 100 meters to 2kg at 1 km or 1 Ton at 200km.
Metric 3	Size of the detectors	From several km to 20m or from ~1m to 0.1m

PERFORMANCE OBSTACLES

The inductive response tends to damp the signal. We plan to mitigate this obstacle by i) exploring various geometries, ii) enhancing the mass of the torus, and iii) detecting lower level currents.

Noise from various sources constitutes another important obstacle, which we plan to reduce by lowering the temperature of the device and by other means.

The static background gravitational field is an obstacle to applications. We plan to effectively nullify this background field by an appropriate arrangement of masses near the detector.

TECHNICAL READINESS LEVEL

TRL at effort start: 1

TRL at effort completion: 3

Part 2. Superconductivity and Aharonov-Bohm effect

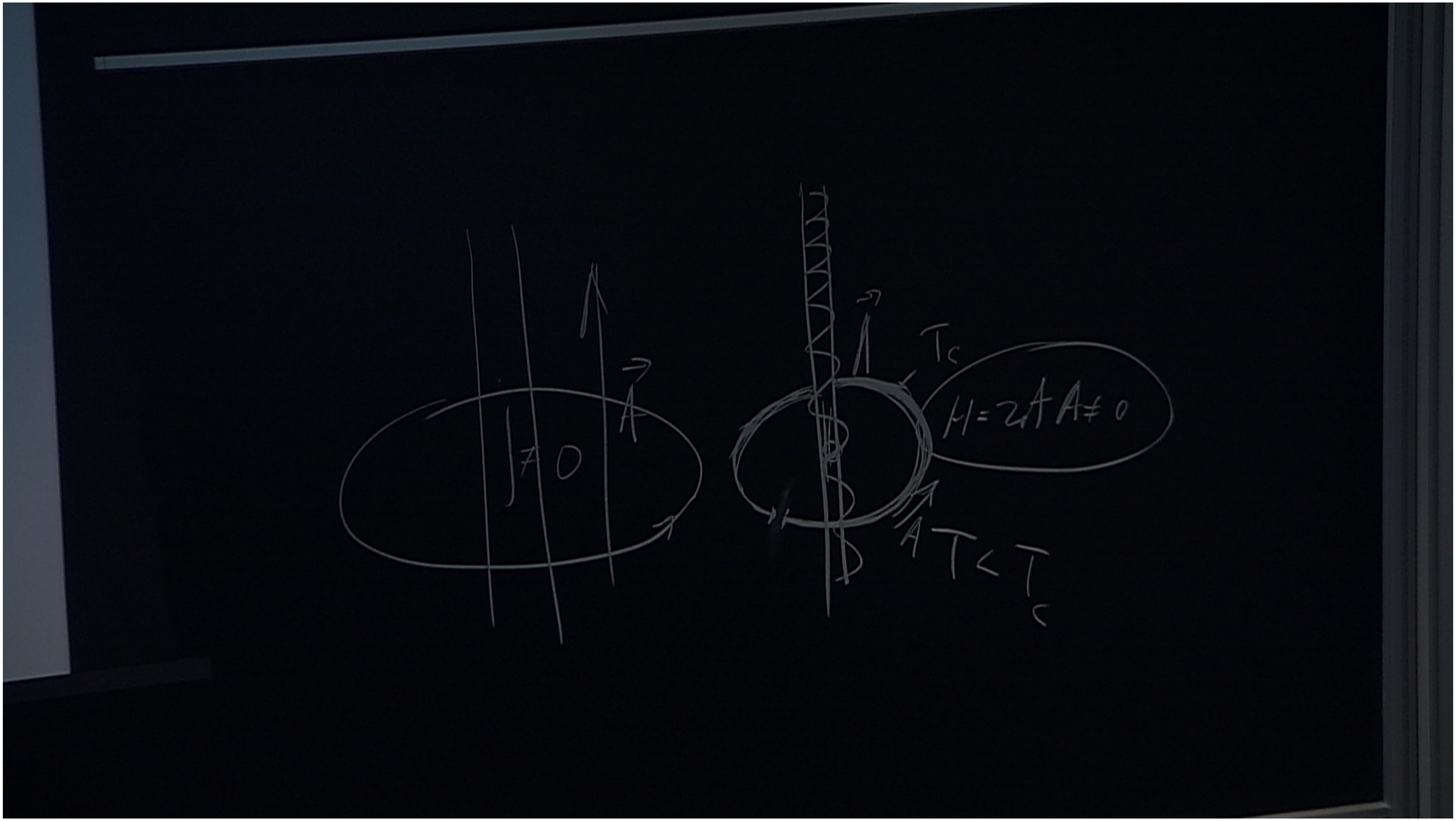
(Quantum sensing of vector potential)

Armen Gulian (sole responsibility)
(Chapman University)

$$j \propto -A \qquad\qquad \psi = |\psi| \exp(i\theta)$$

$$j \propto -A + \nabla\theta$$

$$A \to A + \nabla f \qquad\qquad \theta \to \theta + f$$


j ≠ 0
A
T_c
H = 2A A ≠ 0
A T < T_c

Meissner response of superconductors: Quantum non-locality vs. quasi-local measurements in the conditions of the Aharonov-Bohm effect

Armen M. Gulian
Advanced Physics Laboratory, Chapman University, 15202 Dino Dr., Burtonsville, MD 20866

Dedicated to Prof. Y. Aharonov on his 80th birthday

Abstract – Theoretical explanation of the Meissner effect involves proportionality between current density and vector potential [1], which has many deep consequences. Amongst them, one can speculate that superconductors in a magnetic field "find an equilibrium state where the sum of kinetic and magnetic energies is minimum" and this state "corresponds to the expulsion of the magnetic field" [2]. This statement still leaves an open question: from which source is superconducting current acquiring its kinetic energy? A naïve answer, perhaps, is from the energy of the magnetic field.

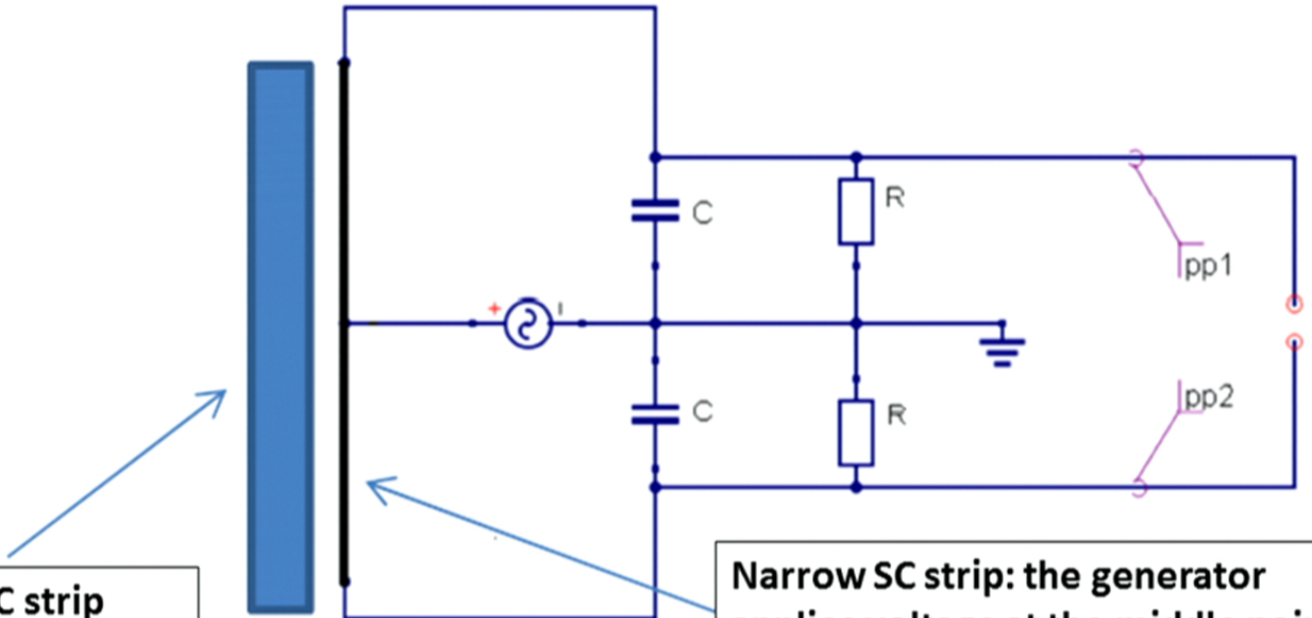
However, one can consider situations (Aharonov-Bohm effect), where the classical magnetic field is absent in the space area where the current is being set up. Experiments demonstrate [3] that despite the local absence of magnetic field, current is, nevertheless, building up. From what source is it acquiring its energy then? Locally, only a vector potential is present. How does the vector potential facilitate the formation of the current?

Is the current formation a result of truly non-local quantum action, or does the local action of the vector potential have experimental consequences, which are measurable quasi-locally?

We discuss possible experiments with a hybrid normal-metal superconductor circuitry, which can clarify this puzzling situation. Experimental answers would be important for further theoretical developments.

Journal of Physics: *Conference Series* **507** (2014) 042012

Suggested principle of the detection

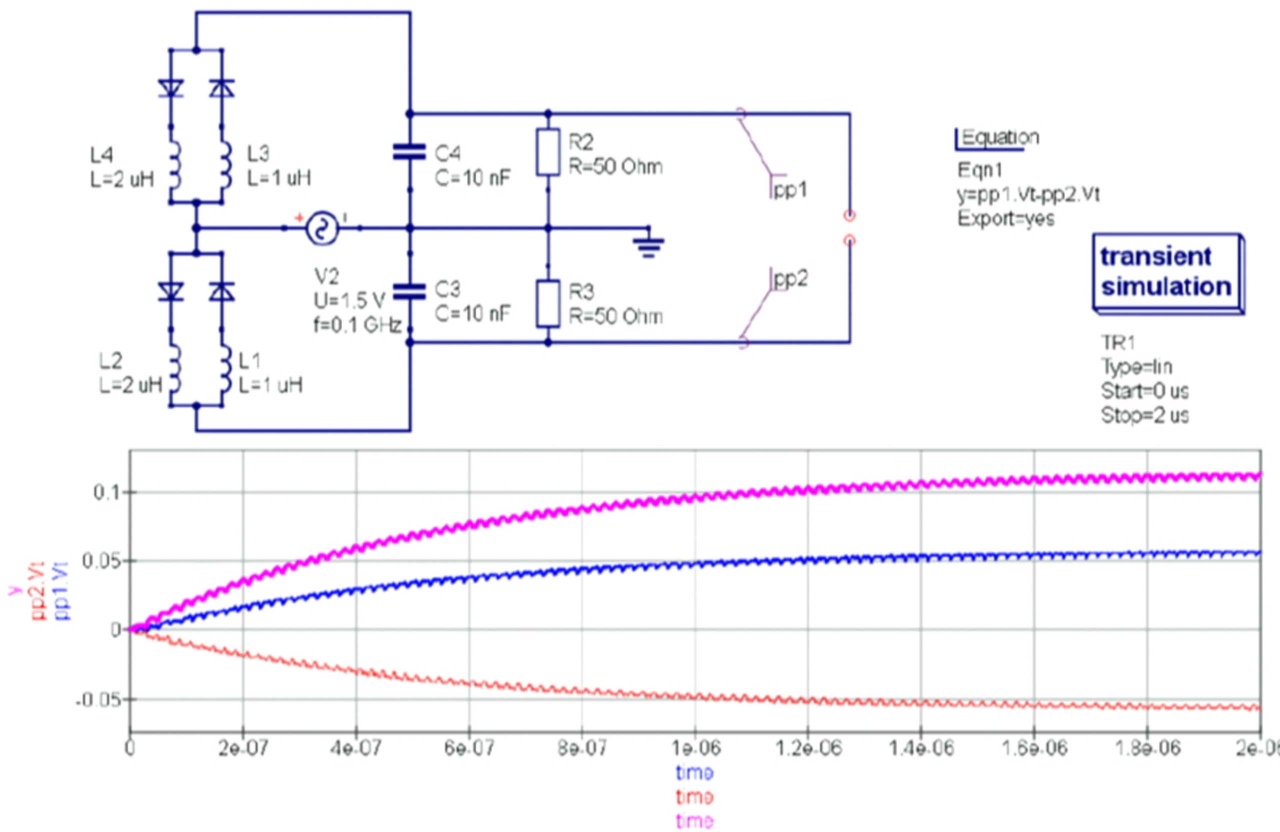


SC strip with current generating field A

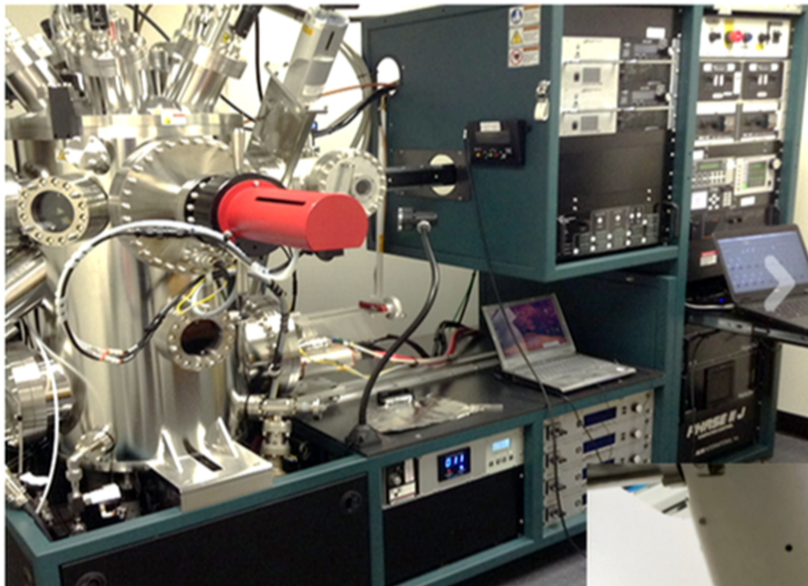
Narrow SC strip: the generator applies voltage at the middle point. Current flows into both circuits, which are symmetric. Except action of A.

11

Modeling results

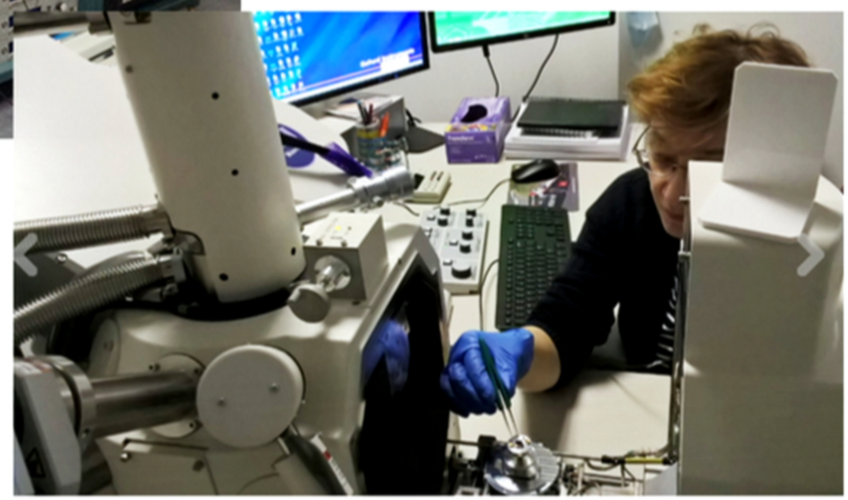


Facilities are getting ready to be used



for this task.

Students, collaborators are welcome!



Thank you!