Armen Gulian (brief biography)

Background

A. Gulian received his M.S. degree in theoretical Solid State Physics (Superconductivity) (1978, summa cum laude) at the Higher School of Physics organized by the Nobel Laureate N. Basov at the Moscow Engineering-Physics Institute (currently the National Research Nuclear University, or MIFI). As an undergraduate, A. Gulian developed a novel idea for the detection of gravitational waves which allowed him to further his education by setting up a bridge to Prof. V.L. Ginzburg (later Nobel Laureate) and his group at P.N. Lebedev Physics Institute. This resulted in a PhD Thesis in Theoretical & Mathematical Physics defended in 1981 at the same Institute. The Thesis generalized the so-called kinetic equations of Eliashberg to include the nonequilibrium phonon system into consideration. A major practical corollary of this result was the prediction of the “phonon deficit” effect, which was later shown to facilitate a “cooling by heating” engine. During his postdoctoral research at the same Institute, he developed a series of other theoretical topics in fields of nonequilibrium superconductors and superfluid helium-3. In 1990, he received a degree titled Doctor of Physical & Mathematical Sciences (Soviet Degree, similar to Habilitation in the German system) for this series of explorations. In the same year he published, jointly with Dr. G.F. Zharkov, the world’s first monograph on Nonequilibrium Superconductivity. Later (1999), its English translation was published by Plenum Publishers. One of the major topics of development at this time was the theory of superconducting quantum generators. Experimental implementation of an acoustic quantum generator started in Moscow under his guidance.

This research was interrupted by the discovery by Bednorz and Mueller: Armenian authorities invited Dr. Gulian to set up a laboratory of High-Temperature Superconductivity (HTSC). The newly initiated research was very successful, and included, among other things, a report on the Josephson coupling in granular YBCO materials in the first Soviet collection of articles on HTSC; a report on the first Soviet BSCCO superconducting film; and some others. This initial success allowed for the submission of a winning proposal on Nonequilibrium phenomena in HTSC, which delivered support for 4 years with an annual budget exceeding $1,000,000. During the collapse of the Soviet Union, a Meyer Foundation Grant (awarded by the American Physical Society), as well as the support of the Soros Foundation allowed the research to continue. However, it was not sustaining, and there was no alternative to emigration.

Between 1994 - 2010 Dr. Gulian has been affiliated with the US Naval Research Laboratory (Washington DC), where he developed novel concepts of cryogenic single-photon detectors. One of these concepts, the so-called “sigma-detector”, can be considered as the predecessor of the kinetic inductance detectors. The second, the so-called “myu-detector”, later coined into the “QVD-detector”, was patented by the NRL and experimentally demonstrated in the lab. During the NRL-period of his research, Dr. Gulian suggested utilizing the Cooper condensate of triplet superconductors as qubits for quantum computing. To materialize this idea, laser processing of strontium ruthenate triplet superconductor crystals was performed. Serendipitously, these samples revealed signatures of superconductivity at 200-250K temperature. The NRL patented these finding, however, no conditions were available to continue the research there. It was necessary to find another home for this important research direction.

In 2008-2009, while doing research at the NRL, Dr. Gulian developed physical models for Brillouin avalanches triggered in optical fibers by the phonon injection. This research captured the interest of the Office of Naval Research for cryogenic communication tasks, and using this ONR support, Dr. Gulian had set a small research lab at Chapman University. Since then, more research topics came into the spotlight, and currently the lab possesses very advanced facilities for materials research, including: clean room; ceramic synthesis and characterization facilities (furnaces, XRD, TGA, cryostats); advanced multitask thin-film deposition system; laser-processing system with picosecond UV-visible-IR laser; SEM-microscopes with EDX, WDX and EBSD, equipped with 50 nm E-beam lithography; photolithography; laser lithography; SQUID-magnetometry down to 250mK; FTIR cryogenic spectroscopy (including THz facilities); Raman Microscopy; COMSOL Multiphysics finite element modeling facilities; cluster for fast ab-initio computation using ABINIT with the DP-package and QuantumWise Software license.

Current Research Topics

<u>1. Search for novel superconducting materials</u>

This topic is of the utmost importance. Recently, with his colleagues, Dr. Gulian published a report [https://www.worldscientific.com/doi/abs/10.1142/S0217984920504151] on ideal diamagnetic response at room temperature by a graphene-n-heptane-permalloy system. They found that perfect screening of sub-milligauss magnetic fields (ideal diamagnetism) by a system comprised of a graphene and thin permalloy foil parallel to the graphene layer immersed in n-heptane occurs at room temperature. The observed ideal diamagnetic feature is either a footprint of a novel type of superconductivity at room temperature or a yet unknown quantum phenomenon in condensed matter physics. The obtained results did not allow the authors to rule out superconductivity as a possible cause of the detected effects. However, if this is room-temperature superconductivity at ambient pressure, it has an unusual property: “freezing” of the diamagnetic moment. This pronounced exotic effect needs an explanation either within the framework of superconductivity or an alternative should be found for both it and the ideal diamagnetism itself.

Dr. Gulian also developed facilities for laser processing of ceramic precursors. The aim is to create nonequilibrium synthesis conditions (high pressure created by expansion of the laser plume in the groove inside the ceramic material, combined with extremely high temperatures and fast cooling) that can help in reaching islands of metastability for crystalline configuration of materials that are otherwise inaccessible. The goal is to demonstrate superconductivity in small amounts of materials, exploring ways of ensuring the reproducibility of results and modifying the compositions/processing conditions in order to elevate T_c as high as possible.

This research is currently supported by the ONR.

2. Quantum physics and devices

Is vector potential just a mathematical tool or it is a physical reality? The belief is that it is just a mathematical tool in the world of classical objects, but it is a physical reality in a quantum world. Can we apply quantum objects such as superconductors, to locally reveal the presence of the vector potential when any classical manifestation is absent (for example, in the conditions of the Aharonov-Bohm effect)? Experimental answer to this question is of a great importance for science. It also can constitute a basis for sensitive quantum devices. Dr. Gulian and his colleagues explored and elaborated upon ideas for this topic, and implementations are in progress.

Another quantum device is a superconducting laser. Such an instrument could serve as a compact source of coherent THz radiation with numerous applications. The concept exploits the analogy between semiconductors and superconductors. However, the analogy is not complete and requires further exploration. As was mentioned above, Dr. Gulian made major contributions to the development of its theory. The increase of available superconducting materials by recent discoveries makes the task much more plausible.

Both of these tasks are of interest to the ONR fundamental research (6.1) program.

3. Gravitational wave detectors and gravity gradiometers

The recent detection of gravitational waves by LIGO detectors attracted a lot of attention and appreciation. What are the next steps? Can a detector that is more compact, more affordable, and more sensitive be designed? It appears that superconductors can do the trick. For many years, Dr. Gulian with his colleagues has been developing the design for such a detector. Interestingly, GW detectors (after simple modification) can work as gravity gradiometers. The ideas and laboratory prototypes of these instruments are currently being explored.