ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

CRT/DET - Novel quantum devices and methods for the metrology of electric current

Funded By	FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014] Dipartimento DET
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Context of the research activity	The objectives of this research project are the development and the investigation of quantum-based measuring systems for the primary metrology of low electric currents. Specifically, this research project aims at developing transresistance amplifiers in which the transresistance is defined by graphene quantum Hall array resistance standards, and at contributing to investigating the potentiality of dual Shapiro steps in Josephson junctions as primary standards of current.
Objectives	In the International System of Units, all units are currently defined in terms of seven defining constants with assigned exact values, and all units can be realized by exploiting a number of fundamental quantum effects producing quantized quantities related to the defining constants. The unit of electric current, the ampere, can be realized in a direct way by means of single electron devices or in an indirect way by combining through the Ohm's law a quantum Hall resistance standard with a Josephson voltage standard. However, at present, due to technological limitations, there is a gap from 100 pA to 1 µA which is not covered by these methods with state-of-the-art accuracy. This research project, which is in collaboration with the Istituto Nazionale di Ricerca Metrologica (INRIM), the Italian national metrology institute, and other national metrology institutes worldwide, aims at contributing to filling this metrological gap in two ways. Transresistance amplifiers are commonly used in electronic instrumentation to measure low currents, from tens of femtoampere to milliampere. However, the transresistance of common amplifiers is composed of industrial resistors which are not intrinsically traceable to the SI unit of resistance, are subjected to drift and need periodic calibrations. To overcome these issues, one goal of

	this research project is to develop low-noise, intrinsically traceable transresistance amplifiers in which the transresistance is defined by graphene quantum Hall array resistance standards. These devices are networks of quantum Hall resistance standards of single-layer graphene producing quantized resistances which are accurate fractions of the von Klitzing constant. With a one-megaohm quantum Hall array resistance standard, such a quantum transresistance amplifier would allow the measurement of currents up to about one microampere with unprecedented accuracy. The second goal of this research project is to collaborate with other institutions to investigate the metrological properties of a recently discovered effect which can be considered the dual of the Josephson effect. In fact, it has been demonstrated that under high-impedance boundary conditions Josephson junctions can generate current Shapiro steps, producing quantized constant currents which can potentially be exploited to establish a new type of quantum current standard.

Skills and competencies for the development of the activity	Ideal candidates should have knowledge of design and application of graphene quantum Hall resistance standards, electronic circuit design and usage of instrumentation for electrical metrology. Candidates should also be available to travel for an extended period abroad.