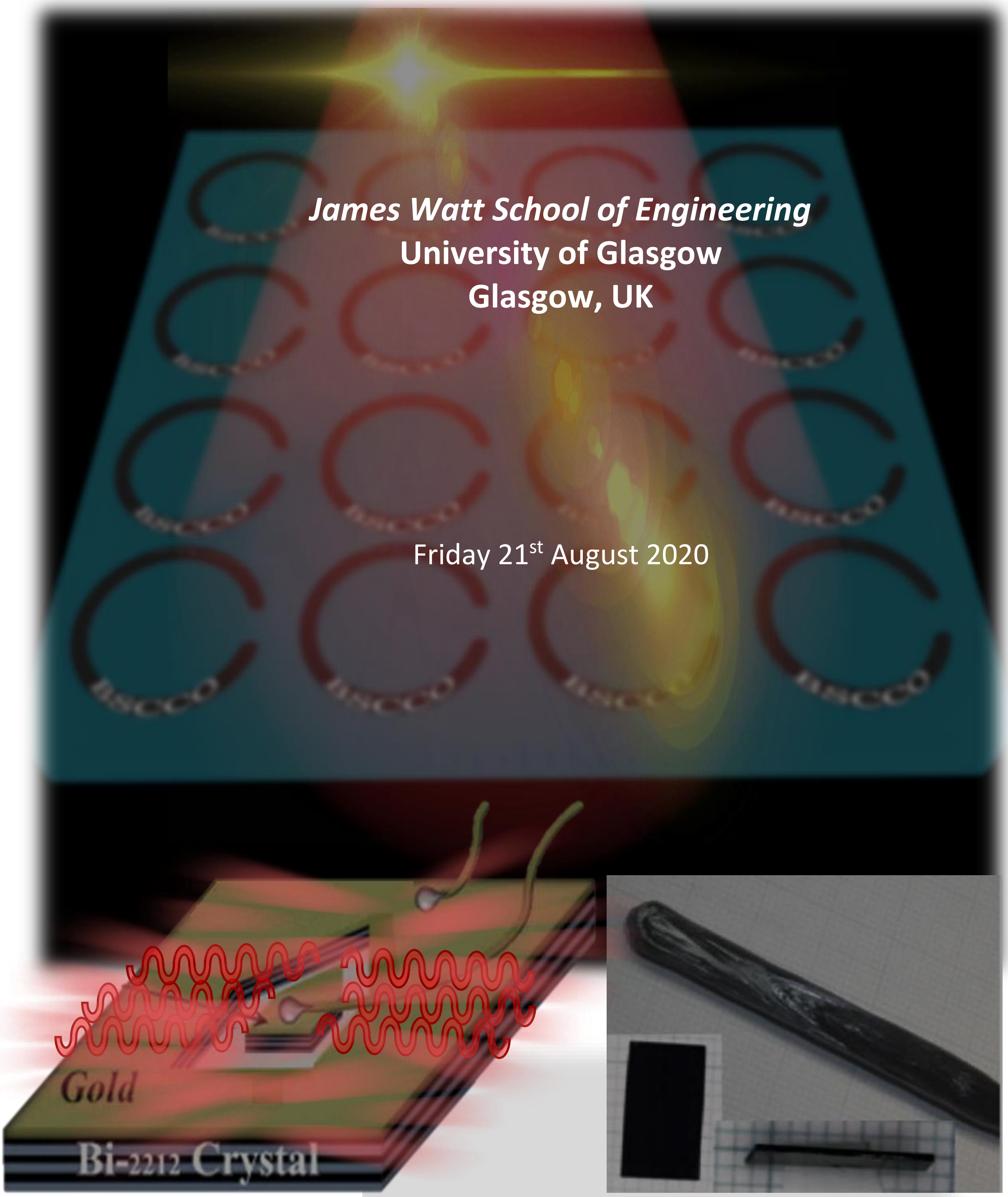
Superconducting Terahertz Device 2020

(STD20)



James Watt School of Engineering
University of Glasgow
Glasgow, UK

Friday 21st August 2020

University of Glasgow

UK-China Emerging Technologies Conference

IEEE Antennas and Propagation Society

The *Superconducting Terahertz Device* 2020 (STD20) workshop brings together the leading scientists in high-T_c superconductivity to discuss the latest advances in superconducting terahertz (THz) components and systems based on intrinsic Josephson junctions, to help shape the future of such THz devices in spectroscopy, imaging, tomography, communication and quantum technology.

- **Plenary Speakers**

Kazuo Kadowaki, University of Tsukuba, Japan

Fedor Kusmartsev (InstP, HEA and APS Fellow), Loughborough University, UK

Richard A. Klemm, University of Central Florida, USA

Huabing Wang, Nanjing University, China

Alexei E. Koshelev (*APS Fellow),* Argonne National Lab, USA

- **Invited Speakers**

Yury Shukrinov, Bogoliubov Laboratory, Moscow, Russia

Itsuhiro Kakeya, Kyoto University, Japan

Takanari Kashiwagi, University of Tsukuba, Japan

Timothy Benseman, CUNY Queens College, USA

- **Organiser**

Kaveh Delfanazari, University of Glasgow, UK

Programme

Workshop on Superconducting Terahertz Device 2020

Friday 21st August 2020 12:50 – 17:30

STD20 Workshop Zoom Link: https://uofglasgow.zoom.us/j/92185074687

Note:

-The time indicates British Standard Time (GMT+1).

-If you have any difficulty in accessing the technical session, please go to the main UCET conference Zoom link to get support.

Time	Paper Title	Authors
12:50	STD 2020 Opening	Kaveh Delfanazari & Kazuo Kadowaki
13:00	Recent Advances in THz Emission from High- T_c Superconducting IJJ Mesa Structure	Kazuo Kadowaki
13:30	The Terahertz Device from hybrids of superconductors and topological materials	Fedor Kusmartsev
14:00	Evaluation of terahertz emission from intrinsic Josephson junction stacks	Huabing Wang, Valery Koshelets, Reinhold Kleiner, & Peiheng Wu
14:30	Mutual Synchronization of Terahertz Emissions from Multiple Intrinsic Josephson Junction Mesas	Ken Hayama, Shuma Fujita, Yuya Kuriyama, Keiichiro Maeda, Manabu Tsujimoto, & Itsuhiro Kakeya
14:50	/	/
15:10	Terahertz Emission from Thin Annular and Slitted Annular Bi2212 Microstrip Antennas	Richard A Klemm, Nahi Shouk, Sheila Bonnough, Ruqayyah Shouk
15:40	Competing steady states in intrinsic Josephson junctions	Alexei E. Koshelev, Dusan Stosic, Darko Stosic
16:10	Development of Bi2212-THz emitter	Takanari Kashiwagi
16:30	Magnetization Dynamics Features in the SFS φ_0 Josephson Junction	Yury Shukrinov, Ilhom Rahmonov, Andre E. Botha, Andrej Plecenik, Dragos Angel
16:50	Stacked Intrinsic Josephson Junction $Bi_2Sr_2CaCu_2O_8$ Terahertz Sources: Design Issues for Achieving High Power Output Close to T_c	Timothy M Benseman, Karen Kihlstrom, Alexei Koshelev, Ulrich Welp, Wai-Kwong Kwok, & Kazuo Kadowaki
17:10	Guiding of Terahertz Photons in Superconducting Nano-Circuits	Samane Kalhor, Majid Ghanaatshoar, & Kaveh Delfanazari
17:30	STD 2020 Closing Remarks	Kaveh Delfanazari

[Talk P1]

Recent Advances in THz Emission from High T_c Superconducting IJJ Mesa Structure

Kazuo Kadowaki
University of Tsukuba, Japan

Electromagnetic waves at THz frequency can be generated coherently and continuously by using high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ mesa structure. After more than decade-long research and development of THz emission from superconductor we now come to a stage to develop THz emitting devices useful for many applications. I will give a brief summary of such THz emitting devices for commercial use with high performance.

About the speaker

Kazuo Kadowaki (Member, IEEE) received the Ph.D. degree in physics from Osaka University, Suita, Japan, in 1980. He worked as a Postdoctoral position at the Department of Physics, University of Alberta, Edmonton, AB, Canada, from 1982 to 1986, a Lecturer with the Natuurkundig Laboratorium der, Universitaeit van Amsterdam, Amsterdam, The Netherlands, from 1986 to 1990, a Group Leader with the National Research Institute for Metals, Tokyo, Japan, from 1990 to 1995, and an Associate Professor with the Institute of Materials Science, University of Tsukuba, Tsukuba, Japan, in 2005, where he has been a Professor since 2007. He has discovered Kadowaki–Woods law in solid-state physics and experimentally proved the Josephson plasma waves in layered superconducting BSCCO intrinsic Josephson junctions (IJJs) for the first time.

[Talk P2]

The Terahertz Device from Hybrids of Superconductors and Topological Materials

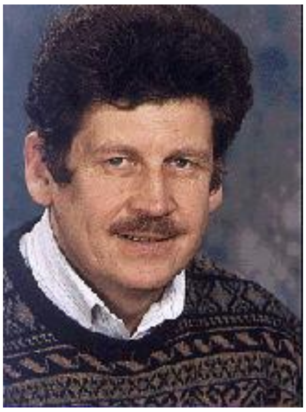
Fedor Kusmartsev

Department of Physics, Loughborough University, UK

In my lecture I am going to speak about unique device which will unlock the illusive terahertz (THz) wavelengths and make revolutionary new technologies possible on the bases of the novel hybrid structures[1-3] from topological materials and superconductors [4-6].   Such devices have a simple structure consisting of graphene or a thin film of topological material(TM) and a superconductor(SC). As the THz light falls on the proposed TM/SC device it is reflected, and simultaneously is strongly amplified using the energy supplied by a battery or by pumping light of a higher frequency. The THz photons are transformed by the TM/SC structure into energised massless electrons, which, in turn, are transformed back into reflected, energised, THz photons[1]. The TM/SC combination characterized by quantum capacitance and infinite Berry curvature, can be utilized to make THz devices with huge sensitivity[3]. For TM layer we may use two-dimensional Dirac materials such as silicene, germanene, stanene, their heterostructures, as well as arrays of polyacetylene chains and carbon nanotubes, topological insulators and Weyl semimetals. The new device will allow the harnessing of the illusive bandwidth and create the next generation of medical testing, drugs and explosive detection, and wireless communication equipment. There will be a special focus in my lecture on the fast detection of viruses, including the novel coronavirus, which emit different but weak THz signals.

[1] Physical Review Letters, 124(8), p.087701, (2020), [2] Science Bulletin. doi:10.1016/j.scib.2020.05.013 (2020), [3] 2D Materials, 6(4). doi:10.1088/2053-1583/ab2ee9 (2019), [4] Physical Review B, 99(6), p.060501. (2019), [5] Physical Review B, 100(18). doi:10.1103/PhysRevB.100.184509, [6] Physical review B: Condensed matter and materials physics. doi:10.1103/PhysRevB.98.064502

About the Speaker



Fedor Kusmartsev (IOP, HEA, and APS Fellow) received his PhD from the Landau Institute for Theoretical Physics, Russia, in 1983. He is currently Professor of Condensed Matter Theory, and Vice Head of Physics Department, at Loughborough University, UK. He was Research Scientist at the Landau Institute, Moscow (1983), Visiting Professor at Tokyo University (1993), Visiting Professor at NORDITA (1994), Professor of Physics at Loughborough University (1996), and Head of Physics Department at Loughborough University (2001).

[Talk P3]

Evaluation of Terahertz Emission from Intrinsic Josephson Junction Stacks

Huabing Wang,[1,2] Valery Koshelets,[3] Reinhold Kleiner,[4] and Peiheng Wu[1, 2]
[1]*Research Institute of Superconductor Electronics, Nanjing University, Nanjing 210023, China*
[2]*Purple Mountain Laboratories, Nanjing 211111, China*
[3]*Kotel'nikov Institute of Radio Engineering and Electronics, Moscow 125009, Russia*
[4]*Physikalisches Institut and Center for Quantum Science in LISA+, Universitaet Tuebingen, D-72076 Tuebingen, Germany*

Superconducting terahertz (THz) signal sources are very promising in radio astronomy, space communications, and many other applications. In this talk, we will review our efforts on evaluation of THz radiation from $Bi_2Sr_2CaCu_2O_{8+\delta}$ intrinsic Josephson junction (IJJ) stacks.

At high bias, in the presence of a hot spot, the emission frequency seems to be continuously tunable by changing the bias current and the bath temperature. By contrast, at low bias the emission frequencies f are remarkably discrete and temperature independent for both stacks. The total voltage V across the stack varies much stronger than f, and there seems to be an excess voltage indicating groups of junctions that are unlocked.

We have developed a self-mixing technique for the purpose of evaluation. We find that at high bias currents, when a hot spot has formed in the stack, the power level of self-mixing can be low and sometimes is even absent at the THz emission peak, pointing to a good phase locking among all IJJs. By contrast, at low bias currents where no hot spot exists, the self-mixing products are pronounced even if the THz emission peaks are strong. While these observations are helpful for the task to synchronize thousands of IJJs, the observation of self-mixing in general may offer a simple method in evaluating the coherence of THz radiation produced by the IJJ stacks.

Using a Nb/AlN/NbN integrated receiver for detection, we carry out measurements of the linewidth Df of terahertz radiation emitted from intrinsic Josephson stacks. Thanks to the high frequency resolution, we find at high bias, where a hot spot coexists with regions which are still superconducting, Df turns out to be as narrow as 23 MHz, while at low bias we find Df to be not smaller than ~500 MHz. We attribute this to the hot spot acting as a synchronizing element.

We have also used a high-Tc Josephson junction as a terahertz detector. We couple the terahertz radiation to an $YBa_2Cu_3O_{7-d}$ grain boundary Josephson junction mounted on a lens 1.2 cm away. The emitter radiates at frequencies near 0.5 THz, with a maximum emission power, as detected by a Si bolometer, of 25 mW. This emission power is strong enough to induce up to 7 Shapiro steps in the YBCO Josephson junction, indicating the THz emitters are practically useful.

To conclude, with different methods we have evaluated the radiation from the high-Tc Bi2Sr2CaCu2O8+x intrinsic Josephson junction stacks. With the obtained knowledge, the next step can be to develop integrated high-Tc receivers and emitters, and find their practical applications.

This work has been done in collaboration with Mengyue Li, Deyue An, Huili Zhang, Ya Huang, Min Ji, Xianjing Zhou, Hancong Sun, Nickolay Kinev, Takeshi Hatano, Dieter Koelle et al.

We gratefully acknowledge financial support by the National Natural Science Foundation of China (Grants Nos. 61727805, 11961141002, 61521001, 61771235), the National Key R&D Program of China (Grant Nos. 2018YFA0209002, 2016YFA0301802), Jiangsu Key Laboratory of Advanced Techniques for Manipulating Electromagnetic Waves, the Priority Academic Program Development of Jiangsu Higher Education Institutions (PAPD), the RFBR Grant No. 17-52-12051, EU-FP6-COST Action CA16218 and the Deutsche Forschungsgemeinschaft via project KL930-13/2.

About the Speaker

<u>Huabing Wang</u> received his B. S. and Ph.D. in Radio Physics from Nanjing University, China, in 1990 and 1995 respectively. In 1995 he joined the Department of Electronic Science and Engineering, Nanjing University, China, as a staff member and was appointed associate professor in 1996. Since 1997, he was a research fellow of the Japan Science and Technology Corporation, working in the Research Institute of Electrical Communication, Tohoku University, Japan, where he was promoted to be an associate professor in 2001. After visiting the Universitaet Erlangen-Nuernberg, Germany for one year, he spent two years as an ICYS research fellow in the National Institute for Materials Science, where he has been employed as a principal researcher and then chief researcher since 2006. He is now a full professor in Nanjing University. His research interest is superconductor electronics (fabrication, characterization, design, and quantum property and nonlinear dynamics of superconducting electronic devices) and its applications in terahertz and microwave bands.

[Talk P4]

Terahertz Emission from Thin Annular and Slitted Annular Bi2212 Microstrip Antennas

Richard A Klemm[1], Nahi Shouk[1,2], Sheila Bonnough[1], Ruqayyah Shouk[1,2]

[1]*Department of Physics University of Central Florida Orlando, USA*

[2]*Jazan University, Saudi Arabia*

The transverse magnetic wave functions generated from the intrinsic Josephson junctions in the high-temperature superconductor Bi2212 are found for annular and singly slitted microstrip antennas. From the wave functions, the Love equivalence principles are used to generate the emission from the uniform and cavity modes (wave functions). For most of the annular wave functions, the infinite degeneracy of the modes with line nodes through the geometric center most likely will result in no cavity mode enhancement of the output power. Forming the slit breaks that infinite degeneracy into a double degeneracy of modes that are odd or even about the slit. Pictures of the wave functions and the uniform and cavity mode contributions to the output power distribution will be shown. The consequences for forming arrays of such devices will be discussed.

About the Speaker

Richard A. Klemm (Member, IEEE) received the Ph.D. degree in physics from Harvard University, Cambridge, MA, USA, in 1974. He wrote his doctoral thesis, Layered Superconductors, on the theory of such materials in 1974. After a Postdoctoral Fellowship with Stanford University, Stanford, CA, USA, he spent significant amounts of time with Iowa State University, Ames, IA, USA, Exxon Research and Engineering Company, Annandale, NJ, USA, and the Argonne National Laboratory, Lemont, IL, USA. He is currently a Professor of physics with the University of Central Florida, Orlando, FL, USA. Prior to entering Graduate School, in 1970, he synthesized the first highly layered superconductor, TaS2(pyridine)1/2. He is the author of Layered Superconductors (Oxford University Press, Volume 1, 2012).

[Talk P5]

Competing Steady States in Intrinsic Josephson Junctions

Alexei E. Koshelev[1], Dusan Stosic[2], Darko Stosic[2]
[1]*Materials Science Division Argonne National Laboratory Lemont, U.S.A.*
[2]*Centro de Informática, Universidade Federalde Pernambuco, Av. Luiz Freires/n,50670-901, Recife, PE, Brazil*

Intrinsic Josephson junctions (IJJs) in high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (BSCCO) emerged as a promising platform for the development of coherent and continuous terahertz sources [1]. THz radiation is generated in the resistive state due to ac Josephson effect. The development of powerful THz sources depends on reliable preparation of stable coherent states. In large-size mesas, such states spontaneously emerge from chaotic states near the cavity resonance. This transition is facilitated by the formation of the dynamic phase kinks [2]. At sufficiently low currents, the system jumps to a static state. We performed large-scale simulations of phase dynamics in IJJ stacks. We systematically explored the emergence of coherent states and switching to static state for stack with different sizes, dissipations, thermal noise, and disorder. We found that the coherent states are formed only when dissipation exceeds a certain critical value. Below this value, the system switches directly from the chaotic to static state. The critical dissipation level increases with the stack width. It is also higher in nonuniform systems. The chaotic and coherent states coexist within a finite current range and the lifetimes in these states are finite. This means that, for a sufficiently slow current ramp, the system will randomly jump between these states. In this case, the observable voltage is determined by the average between the voltages of two states. This mechanism explains smooth current-voltage characteristics usually observed in experiments on BSCCO mesa structures. It is likely a key factor limiting the performance of existing devices. We confirmed this scenario by performing long-time simulations of a small-size system.

The work was supported by the U.S. Department of Energy, Office of Science, Basic Energy Sciences, Materials Sciences and Engineering Division.

References

[1] U. Welp, K. Kadowaki, and R. Kleiner, Nature Photonics 7, 702 (2013); I. Kakeya and H. B. Wang, Supercond. Sci. Technol. 29, 073001 (2016). [2] S. Z. Lin and X. Hu, Phys. Rev. Lett., 100, 247006 (2008); A. E. Koshelev, Phys. Rev. B 78, 174509 (2008).

About the Speaker

Alexei Koshelev (APS Fellow) is a scientist in the Materials Science Division, Argonne National Laboratory, USA. He received his Ph. D. in 1986 from the Landau Institute of Theoretical Physics (scientific advisor Prof. S. V. Iordanskii). Until 1991 Dr. Koshelev was working in the Institute of Solid State Physics (Chernogolovka, Moscow Region, Russia). During 1991-1993 he was visiting Kamerlingh Onnes Laboratory, Leiden, The Netherlands, where he was developing theory of vortex state in layered superconductors with Prof. Peter Kes. In Argonne Dr. Koshelev is working on theory of superconductivity including vortex matter, intrinsic Josephson junctions, and multiple-band effects.

[Talk I1]

Mutual Synchronization of Terahertz Emissions from Multiple Intrinsic Josephson Junction Mesas

Ken Hayama[1], Shuma Fujita[1], Yuya Kuriyama[1], Keiichiro Maeda[1], Manabu Tsujimoto[2], Itsuhiro Kakeya[1]

[1]*Department of Electronic Science and Engineering Kyoto University Kyoto, Japan*

[2]*Institute for Materials Science University of Tsukuba Tsukuba, Japan*

The authors present direct proof of synchronized macroscopic Josephson oscillations excited in two intrinsic Josephson junction stacks formed on a Bi2212 single crystal. The strong coupling between the Josephson oscillations in the two mesas via the base crystal is probed by polarization analysis of emitted terahertz waves from individually biased mesas and simultaneously biased mesas.

About the Speaker

Itsuhiro Kakeya received a Ph.D degree in June 1998 (Osaka University), 1998-2008: Assistant Professor and Lecturer at University of Tsukuba, Japan, 2008-present : Associate Professor at Kyoto University, Japan Prof. Kakeya is an expert in measuring electric and magnetic responses of superconductors and magnetic materials with a frequency range of 0 – 1012 Hz (DC to THz). In particular, he has an extensively rich experience to measure nanostructured specimen at low temperatures down to 300 mK. He has published over 100 research articles, filled 6 patents, and received 7 grants-in-aid from JSPS-KAKENHI as the research leader. Furthermore, he has supervised 3 Ph.D theses and accepted 1 Postdoc as the leader of his research group since 2013. Research highlight of him include observation of Josephson plasma resonance in superconductors and demonstration of the emission of terahertz (THz) electromagnetic wave from superconductors. He has initiated research on non-linear dynamics of coupled Josephson junctions included in single crystals of cuprate superconductors with using frequency- and time-domain method. This has led an opportunity to open a pathway for actual superconducting high-frequency device and understanding microscopic carrier and phonon dynamics in superconductors.

[Talk I2]

Development of Bi2212-THz Emitter

Takanari Kashiwagi

Institute for Materials Science University of Tsukuba Tsukuba, Japan

Since the discovery of continuous, coherent THz radiation from intrinsic Josephson junctions (IJJs) constructed in the single crystals of $Bi_2Sr_2CaCu_2O_{8+\delta}$ in 2007, various types of device structures have been developed. According to these studies, thermal management of Joule heat of the IJJ mesa device is an important issue to improve the device characteristics. By using a thermal managed device structure with stand alone type of mesas, the radiation frequencies ranging from 0.3 to 2.4 THz, the emission power of ~30 μW/mesa and the radiation linewidth of 0.2 GHz at ~0.5 THz have been obtained so far. We will show a brief overview of the development of the IJJ-THz emitters in our group.

About the Speaker

Takanari Kashiwagi received his Ph. D. from Osaka University in Physics in 2008. After a postdoctoral fellowship at Osaka University (2008–2009), Assistant Professor of Institute of Materials Science, University of Tsukuba (2009–2014), then Lecturer of Graduate School of Pure & Applied Sciences, University of Tsukuba (2015-).

[Talk I3]

Magnetization Dynamics Features in the SFS Josephson Junction

Yury Shukrinov[1,2], Ilhom Rahmonov[1,3], Andre E. Botha[4], Andrej Plecenik[5], Dragos Angel[6]

[1]*Bogoliubov Lab. of Theoretical Physics Joint Institute for Nuclear Research Dubna, Moscow Region, Russia*

[2]*Dubna State University Dubna, Moscow Region, Russia*

[3]*Umarov Physical Technical Institute Tjik Academy of Science Dushanbe, Tajikistan*

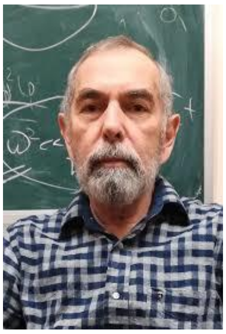
[4]*Department of Physics Unisa Science Campus University of South Africa Johannesburg 1710 South Africa*

[5]*Department of Experimental Physics Comenius University in Bratislava Bratislava, Slovakia*

[6]*Department of Theoretical Physics Horia Hulubei National Institute of Physics and Nuclear Engineering Bucharest - Magurele, Romania*

We investigate the ϕ_0 Josephson junction, which demonstrates a rich variety of dynamical states determined by the parameters of the Josephson junction and intermediate ferromagnetic layer, as well as by the value of the dc-bias current. Results of magnetization dynamics simulation at fixed value of bias current and results of FFT analysis are presented. We discuss how the superconducting current interacts with the different magnetization components.

About the Speaker



Yury M. Shukrinov is a leading scientists of the Joint Institute for Nuclear Research, Dubna and professor of University Dubna, Russia. He had his PhD on Low Temperature Physics and Cryogenic Technique from Moscow State University in 1981. His PhD project was devoted to the band structure and the interband transitions in the semiconducting allows Bi-Sb. Today his research interests are concentrated on the condensed matter physics and theory of superconductivity, particularly, superconducting electronics, tunneling in superconducting structures and intrinsic Josephson effect. He had his second degree of Doctor of Sciences from Bogoliubov Laboratory of Theoretical Physics, Joint Institute for Nuclear Research in 2014 on collective dynamics of coupled Josephson junctions in layered superconductors. He is coauthor more than 150 scientific publications. Yu. M. Shukrinov was a member of the organizing committee and invited speaker of different international conferences.

[Talk I4]

Stacked Intrinsic Josephson Junction Bi2Sr2CaCu2O8 Terahertz Sources: Design Issues for Achieving High Power Output Close to T_c

Timothy M Benseman[1], Karen Kihlstrom[1], Alexei Koshelev[2], Ulrich Welp[2], Wai-Kwong Kwok[2], Kazuo Kadowaki[3]

[1]*Department of Physics CUNY Queens College New York, U.S.A.*

[2]*Materials Science Division Argonne National Laboratory Lemont, U.S.A.*

[3]*Institute for Materials Science University of Tsukuba Tsukuba, Japan*

The high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ contains stacked 'intrinsic' Josephson junctions, with unrivaled packing density and a high superconducting gap energy. Cuboid 'mesa' devices constructed from this material are consequently a promising technology for coherent, continuous-wave radiation in the 'terahertz gap' range, spanning from approximately 0.3 - 1.5 THz. A key issue for practical applications of such devices is their cryocooling requirements, and it is therefore highly desirable to optimize their performance at temperatures that can be achieved by nitrogen cryogenics. Here we report generation of 0.13 milliwatts of coherent emission power at 0.461 THz, at a bath temperature of 77.4 Kelvin. This was achieved by exciting the (3, 0) cavity mode of a stack containing 579 junctions, and with Tc of 86.5 Kelvin. In order to minimize self-heating, the THz source was mounted on a copper substrate using PbSn solder. We will discuss the choice of mesa dimensions and cavity mode, and implications for the design of devices which are intended to operate close to the material's superconducting critical temperature. Funding Acknowledgement: This research is supported by PSC-CUNY Award 60792-00-48; and by the US Department of Energy, Office of Sciences, Materials Sciences and Engineering Division.

About the Speaker

Timothy Benseman is an Assistant Professor in the Department of Physics at Queens College of the City University of New York. His present research primarily focuses on terahertz laser sources based on stacked 'intrinsic' Josephson junctions in the high-temperature superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$, as well as on the fundamental physics of this material. He previously completed postdoctoral appointments at Argonne National Laboratory in the group of Dr Wai-Kwong Kwok, and at the University of Cambridge, in the group of Professor John Cooper. He received his PhD from the University of Cambridge, and also completed an MSc in the group of Professor Jeff Tallon at Victoria University of Wellington in New Zealand.

[Talk I5]

Guiding of Terahertz Photons in Superconducting Nano-Circuits

Samane Kalhor[1], Majid Ghanaatshoar[1], and Kaveh Delfanazari[2,3]

[1]*Laser and Plasma Research Institute, Shahid Beheshti University, G.C., Evin 1983969411 Tehran, Iran*

[2]*James Watt School of Engineering, University of Glasgow, Glasgow G12 8QQ,UK*

[3]*Department of Engineering & Cavendish Laboratory, University of Cambridge, Cambridge CB3 0FA, UK*

The field of plasmonic, as one of the fascinating areas of photonics, has received great attention for its capability of deep subwavelength confinement. We present a nanoscale plasmonic slot waveguide based on high transition temperature (T_c) superconductor $Bi_2Sr_2CaCu_2O_{8+\delta}$ (BSCCO). The effect of geometrical parameters on the modal properties of the BSCCO plasmonic slot waveguide and the thermal tuning of the modal properties of the waveguide are explored. The results indicate the rising of temperature results in increasing the mode effective refractive index in exchange for decreasing the propagation length of surface plasmon polaritons (SPPs). Our proposed plasmonic waveguide paves the way for the development of the BSCCO based THz photonic integrated circuity at the nanoscale.

About the STD20 Organiser

<u>Kaveh Delfanazari</u> (Senior member, IEEE) is an Assistant Professor (University Lecturer) in Electronic and Nanoscale Engineering, at the James Watt School of Engineering, University of Glasgow, UK, and an affiliate Senior Research Scientist at the University of Cambridge, UK. He has held positions as a Research Associate in quantum devices and circuits at the University of Cambridge, UK, Research Fellow, and Project Leader in superconducting and quantum metamaterials, at the University of Southampton, UK. He investigated integrated superconducting terahertz (THz) emitters and antennas- based on Josephson effect- during his PhD work at the University of Tsukuba, Japan. Delfanazari's research group aims at developing on-chip quantum light sources, RF/microwave/mm-waves/THz electronic/photonic integrated circuits, and robust quantum chips based on (hybrid) quantum materials for applications in secure communication systems and decoherence-free (topological) quantum processing and computing.