Short Course at

20th International Vacuum Congress (IVC-20)

Busan, South Korea, 21st August, 2016

http://www.ivc20.com

Title: Vacuum Gas Dynamics: Theory, Experiments and Applications

Lecturers: Prof. Felix Sharipov, Federal University of Parana, Brazil
Prof. Irina Graur, Aix-Marseille University, France
Dr. Oleg Malyshev, Daresbury Laboratory, UK

Aims and motivations: The course is addressed to students, scientists and engineers who are not experts in Rarefied Gas Dynamics but who deals with this field in their routine work. The available textbook and handbooks on vacuum technology usually give just fundaments of gas dynamics but not deep enough to understand the modern state of analytical and numerical methods of modelling in this field. The special literature is often too hard for non-experts. This short course targets at basic research training in Vacuum Gas Dynamics and provides a coherent and rigorous introduction into this field including relevant theoretical and experimental methods for practical applications. No preceding knowledge of gas dynamics is assumed.

Structure of the course: The course duration is 8 hours.

- "Theory", 4 hours, given by Prof. Felix Sharipov
- "Experiments", 2 hours, given by Prof. Irina Graur
- "Applications", 2 hours, by Dr. Oleg Malyshev

Topics:

- **Theory:** Molecular free path, gas rarefaction and flow regimes. Velocity distribution function. Gas-surface interaction. Accommodation coefficients. Free-molecular flows. Analytical solutions in the free-molecular limit. Test particle Monte Carlo method. Velocity slip and temperature jump conditions. Analytical solutions of the Navier-Stokes equations subject to the slip and jump conditions. Intermolecular interaction and kinetic equation. Flows in the transition regime. Discrete velocity method. Direct simulation Monte Carlo method. Main numerical solutions in the transitional regime with examples of their applications: Poiseuille flow, Coutte flow, heat transfer. Transient flows. Numerical models of Holweck and turbo-molecular pumps. Numerical model of Pirani sensor. Rarefied flow calculator. Modelling of gas dynamics processes in vacuum chambers.
- **Experiments:** Specifics of the experiments at micro scale; efficiency of the micro scale experiments to obtain the properties of the rarefied gases. Experimental characterization of the gas-surface interaction. The relations between the theoretical and experimental approaches. Experimental data analysis. Review of main experimental results.
- **Applications:** Design of large UHV vacuum systems in free molecular flow regime. Vacuum specification and input parameters. Experimental data: measurements, data analysis, extrapolation and using. Models: overview of different models used with an emphasis on 1D diffusion analytical model and numerical models (test particle Monte Carlo and angular coefficients), pumps and sources of gas in different models. From a model to a mechanical design. Analysis of errors and uncertainties in a final design. Examples of design.

Didactic material: The participants will get hard and electronic copies of presentations and numerical codes to solve basic problems of vacuum gas dynamics.

Information about the lecturers:

Prof. Felix Sharipov graduated from the Moscow University of Physics and Technology, Faculty of Aerophysics and Space Research in 1982. He obtained his Ph.D. in 1987 at the Ural State Technical University. In 1988 he joined the Physics Faculty of the Ural State University where he set up his activity in rarefied gas dynamics. In 1992 he moved to the Federal University of Parana in Brazil where he built up a group on numerical modelling of gas flows in microscale. His research interests are numerical methods of rarefied gas dynamics applied to microfludics, vacuum technology and aerothermodynamics. His group develops both probabilistic and deterministic approaches. He was an organizer of numerous vacuum gas dynamics meetings and schools. F. Sharipov published over a hundred journal articles, several reviews and chapters in handbooks. He is an author of two books and a member of editorial board of "Vacuum" (Elsevier).

Prof. Irina Graur obtained M.Sc. in applied mathematics in 1984 from Moscow Lomonossov State University. She received a PhD also from Moscow State University in 1989 and the Habilitation from Provence University in France in 2008. Irina Graur was associate professor at Keldish Institute of Applied Mathematics between 1984 and 2000. She is currently professor at Aix Marseille University in France. She has made a number of contributions in the field of rarefied gases for the aerospace research. Her current research interests include the experimental and numerical characterization of the gas properties at micro and nano scales. She heads the research group "Non-equilibrium phenomena and microfluidic" in IUSTI Laboratory. She participated in the organization of a number of international conferences, workshops and summer schools. She has co-authored more than one hundred journal articles and conference papers.

Dr. Oleg Malyshev was graduated in the Physics Department at the Novosibirsk State University in1989. He started his carrier as a vacuum scientist at the Budker Institute of Nuclear Physics where he obtained his Ph.D. in 1995. His work includes theoretical studies, experimental research and design of various vacuum systems such as VEPP-5, ANKA, BESSY, SSC. From 1998 to 2001, he worked at CERN designing the LHC beam vacuum system. Since 2001 he works in ASTeC at STFC Daresbury Laboratory, he designed a vacuum system for Diamond Light Source, participated in R&D for International Linear Collider, FAIR, KATRIN, NLS, ALICE, etc. He leads experimental and analytical study in ASTeC Vacuum Science Group. He is an editor of international scientific journal VACUUM (Elsevier), an organizer of international workshops, meetings, an author of more than 120 scientific papers and reports. He is a Charted Physicist and a Fellow of Institute of Physics.