Non-linear phenomena and dynamics of flame propagation

THEORETICAL ASPECTS AND IMPLEMENTATIONS

21 - 25 of September 2019

Borovoe (Burabay) National Nature Park Kazakhstan

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Conference Schedule

21 September, Registration and Welcome Party
25 September, Farewell

	22	23	24	25
10:00:00	Opening	Z. Mansurov	A. Konnov	
10:25:00	U. Maas	A. Kirdyashkin	A. Mebel	
10:50:00	N. Slavinskaya	P. Bruel	V. Azyazov	*Round table*
11:15:00	*break*	*break*	*break*	
11:35:00	L. Kagan	R. Fursenko	E. Mikheyeva	
12:00:00	H. Nakamura	V. Gubernov	B. Lesbaev	
12:25:00	D. Knyazkov	E. Dats	V. Bykov	
12:50:00	*lunch*	T. Miroshnichenko	*lunch*	
14:20:00	S. Minaev	*banquet*	T. Sugita	
14:45:00	A. Elyanov		S. Takahashi	*Round table*
15:10:00	R. Schiessl		K. Kanayama	
15:35:00	*break*		*break*	
15:55:00	I.Yakovenko		A.Maznoy	Open discussion in combustion physics chemistry
16:20:00	V. Volodin		A. Naimanova	
16:45:00	H. Wang		A. Ponomareva	

Abstracts

22.09.2019

Ulrich Maas	Hierarchical Models for Chemically Reacting Flows
The question arising in mathematical modeling of reactive flows is: How detailed, or down to which scale has each process to be resolved (chemical reaction, chemistry-turbulence-interaction, molecular transport processes) in order to allow a reliable description of the entire process. The aim is the development of models, which should be as simple as possible in the sense of an efficient description, and also as detailed as necessary in the sense of reliability. In particular, an oversimplification of the coupling processes between chemical reaction and turbulent flow should be avoided by all means to allow a predictive character. In the presentation it is shown how hierarchical concepts can be used to solve this problem. Different examples show, that such hierarchical concepts allow a reliable description of reactive flows.	

Vladimir Goldshtein	SINGULAR PERTURBED VECTOR FIELDS OF REACTION-DIFFUSION SYSTEM
The theory of singularly perturbed vector fields represent a coordinate free version of singularly perturbed systems of ordinary differential equations (ODE) that corresponds in chemical kinetics and combustion to pure kinetic systems. It can not count an influence of transport processes on reaction-diffusion system. The main formal object of our study is an ODE combustion model (reaction) with an addition of a comparatively slow transport processes. The main results were illustrated and validated by the well known example of Michaelis-Menten enzyme model extended by the Laplace operator. Effects of the system decomposition, influence of the boundary conditions and diffusion transport were discussed.	

Slavinskaya Nadezda	Digitalisation: best estimate plus uncertainty.
The expanding growth of science data, which are traditionally available through books, published papers and online databases with figures and tables, makes their storage, analysis and handling difficult, ineffective and increases risks of human error. Data transparence, i.e. standards for data presentation, uncertainty quantification, data storage and sharing becomes an important part of the numerical simulation methodologies through their depending on the data availability and data quality. To achieve the full realization of the power of new high-quality data, the priority skills for the progresses in science and engineering is moved to the development of the new paradigm for data management, revolutionizing science and engineering, to the Cyber Infrastructure (CI), data digitalization, with other words – full automation of data-mining process.	

Hongxin Wang	A Modeling Study of Ethylene and Ethane Oxidation
This study reports the upgrade of the DLR reaction database. The upgrade includes an optimization of the C1-C4 oxidation chemistry and a revision of the polycyclic aromatic hydrocarbon (PAH) formation sub-mechanism. The present paper shows the recent improvement of the C2 kinetic mechanism based on validations of ethylene and ethane oxidation. The uncertainty intervals of the studied reactions were statistically evaluated, providing general bounds for the performed modifications to reaction rate coefficients. The model optimization was performed with ignition delay data, laminar flame speed data and concentration profile data. Results from about 40 experiments including shock tube, rapid compressed machine, heat flux method, counterflow flame, Bunsen flame, spherical flame, plug flow reactor and laminar flame structure were used. More than 1000 targets were analyzed. Old reaction rate were replaced and some new channels were add to the mechanism. The new model is capable of predicting	

Hisashi Nakamura	Optimization of rate parameters using genetic algorithm for constructing compact reaction mechanism
A new concept to construct a compact reaction mechanism using genetic algorithm was developed and demonstrated for methane combustion. A reaction pathway from methane to carbon monoxide was designed with two intermediates (fuel radical and aldehyde) and a detailed reaction mechanism of syngas was combined with the designed pathway. Rate parameters of the designed pathway were optimized using genetic algorithm to reproduce combustion properties such as laminar flame speeds and ignition delay times. The prediction of the combustion properties using the optimized compact reaction mechanism was compared with that using the detailed reaction mechanism	

Denis A. Knyazkov	Effect of propylene oxide addition on a fuel-rich n-heptane/toluene flame
The effect of propylene oxide (PO) additive on the composition of intermediate combustion products, including mainly soot	

precursors, in the flame of a fuel-rich pre-mixed n-heptane/toluene/O2/Ar mixture at 1 atm is examined using flame sampling molecular beam mass spectrometry. The experiment clearly demonstrated that PO addition results in ~30% and even stronger reduction in the peak mole fractions of many aromatic intermediates detected in the flames. However, the kinetic mechanism used for the system studied does not reproduce the observed tendencies. The kinetic mechanism for PO combustion wasn't also found to reproduce adequately the $PO/O_2/Ar$ flame speciation data presented in this work. Further efforts are therefore needed to improve the available chemical kinetic model for PO combustion.

Sergey Minaev	Hydrodynamic instability of premixed flame propagating in narrow planar channel in the presence of gas flow
This paper analyzes the hydrodynamic instability of a flame propagating in the space between two parallel plates in the presence of a gas flow. The model includes parametric dependences of the flame front velocity on its local curvature and on the average gas velocity ahead of the flame front. In the absence of influence of the channel walls on the gas flow, the model goes over to the Landau-Darries model. It has been shown that gas friction against the channel walls can lead, in some cases, to a significant increase in instability compared with the instability of freely propagating flame.	

Vladislav V. Volodin	Analysis of the influence of the type of initial conditions on the development of instability for a hydrogen-air flame based on the Sivashinsky equation
The paper presents the results of an analysis of flame front instability using the Sivashinsky equation. The effect of the type of initial perturbations on the dynamics of the flame front in a stationary poor hydrogen-air mixture is investigated. The following initial disturbances were used: random disturbances of various intensity and frequency range, single and double disturbances of rectangular and sinusoidal shape with different values of width and amplitude. The results are presented as dependences of the wrinkling factor versus time. The obtained results explain the experimentally observed variation in the parameters of the acceleration of gas flames.	

Robert Schiessl	Turbulent flame structure derived from reaction field ridges
We apply the newly introduced reaction front identification and analysis method based on ridges. "Ridges" are regions where the reaction field attains local directional maxima along its axes of principal curvature. They offer a natural and fully generic way for reaction front identification in a wide range of combustion types, be it premixed, partially or non-premixed, flame-like or distributed combustion. They also intrinsically accommodate quite complex and varied geometric reaction zone shapes, including flame sheets, spherical blobs and filamentary structures. A method for numerically identifying ridges in a given combustion data set is demonstrated. It is applied to three-dimensional DNS data from non-premixed diluted turbulent H2/air flames.	

Kagan Leonid	Parametric transition from deflagration to detonation revisited: Numerical issues
The presentation is concerned with identification of the key mechanisms controlling deflagration-to- detonation transition in gaseous systems. Depending on the parameters of the system the transition may occur either within the subsonic, sonic or supersonic range of deflagrations. In the latter case the deflagration obeys the classical Chapman-Juguet (CJ) condition. The CJ-deflagration is firstly obtained as an analytical self-similar solution implied by conventional conservation relations assuming the reaction zone to be infinitely thin and accounting for the impact of flame-folding. Also a dynamical model based on a one-step Arrhenius kinetics is simulated numerically. The impact of initial conditions is discussed. Attraction areas for deflagrations, detonations and extinctions in terms of the initiation hot-spot width and flame-folding degree are identified. Deflagration-to-detonation transition (DDT) in terms of the attraction areas is discussed and a passage to DDT is shown.	

Yakovenko Ivan	Evolution of combustion waves in the lean hydrogen-air mixtures with suspended micro-droplets of water
The present study is devoted to the detailed two-dimensional numerical modeling of the propagation of the combustion waves through the hydrogen-based gaseous mixtures with suspended micro-droplets of water. Considered gaseous mixtures are characterized by a relatively low reactivity and so the intensity of the combustion waves is moderate. Thus the low Mach approximation was implemented that allowed significant speed-up of the calculations. Lagrangian micro-droplets of water were modeled with an account of the momentum and energy exchange between gaseous and disperse phases and the release of water steam as a result of evaporation processes. Obtained results allowed to determine the influence of the suspended micro-particles on the flame dynamics in the confined vessel. In particular, it was shown that the interaction between the particles with the diameter larger than 100 μm and the flame front results in the enhancement of the development of the flame surface instability that provides a substantial acceleration of the mixture burn-out process in the volume. The research was financially supported by the Russian Foundation for Basic Research (grant №18-38-20079). Computational modeling was performed via computational software developed with the support of the Program of the Presidium of RAS "Mechanisms of fault tolerance assurance of the contemporary high-performance and high-reliable computations".	

Artem E. Elyanov	Dynamics of development of a cascade of heterogeneities for a spherical hydrogen-air flame
The paper presents the results of infrared and schlieren visualization of the spherical propagation of a hydrogen-air flame in a quiescent mixture. For the first time, an IR shooting of a spherically expanding flame front with ultrashort exposure times was carried out. The applied imaging technique allowed us to reveal the structures of the flame front, the surface wrinkling factor of which significantly exceeds all previously obtained ones. Experimental photographs are subjected to automated processing with the selection of the main scales of inhomogeneities. The dynamics of the sizes of the observed inhomogeneities are analyzed. The development of subsequent harmonics of flame front inhomogeneities is shown and the relationship between the sizes of inhomogeneities of the subsequent stages is established.	

23.09.2019

Alexander Kirdyashkin	Filtration combustion of natural gas for the synthesis/sintering of refractory ceramics
This work studies the conditions for the formation of ceramic materials in the temperature field created by the wave of filtration combustion of natural gas (92% CH4) and air inside the filling of balls ZrO2 (ϕ 5mm). Variations in the feed rate and composition of the combustible mixture is found to change the combustion rate in the range of + 0.15 ÷ -0.07 mm/s and the filling temperature behind the wave in the range of 700 ÷ 1900 °C. The test heat treatment of initial powder mixtures behind a combustion wave at a temperature of 1600÷1650 °C for 1 hour showed almost complete conversion of the powder mixture Si + 30% C into a composite SiC – Si2N2O; the MgO powder into in dense periclase (porosity less than 15%). This work was supported by state budget project №0365-2019-0004 and RFBR №18-48-700037.	

Mansurov Z.A.	The development of chemical physics and processes of combustion in Kazakhstan
The development of Chemical Physics in Kazakhstan is related to the study of gaseous phase flames, with the research of applicable characteristics of inhibition of gaseous and condensed system, and also connected to the SHS-refractories with enhanced characteristics. These works were started early 60s under the direction of Prof. Ksandopulo G. I. by the support of academicians Semenov N.N., Zeldovich B. Ya. and Merzhanov A.G. In present time in Institute of Combustion Problems by the direction of Prof Mansurov Z.A. the research of nanomaterials formation in hydrocarbon flames is conducted. Based on the data on synthesis of fullerenes, carbon nanotubes, super-hydrophobic soot and graphene in the flame, it is possible to modify the general scheme proposed by H. Bockhorn for rich fuel flames, to introduce a pressure-coordinate, which allows the formation of fullerenes at low pressures, and soot at high pressures. In addition, the scheme was completed by graphene formation as an intermediate product stage of soot formation.	

Pascal Bruel	Pressure based methodologies for zero Mach and low Mach flows simulations
One fundamental difference between zero Mach and low Mach flows configurations is the presence of acoustic waves in the latter case. Thus, this is obviously conditioning the type of methodology than can be used to simulate either type of flows. We shall present two pressure-based strategies to cope with these two situations: the artificial compressiblity method for zero Mach reacting flows and the Momentum Interpolation with Advection Upstream (MIAU) splitting method recently developed for non reacting low Mach flows but which could be a good candidate for future low Mach reacting flow simulations.	

Vladimir Gubernov	On the diffusive-thermal pulsations of the burner stabilized flames
In this talk we will overview our recent results on the numerical modelling and experimental observation of the diffusive-thermal instabilities of the burner stabilized methane-air flames. The numerical simulations is conducted within a one-dimensional model with detailed reaction mechanisms, while the experimental studies are done by using visual imaging, spectroscopic and acoustic measurements. The critical conditions for the emergence of flame oscillations and the period of pulsations are determined. The experimental data are found to be in good agreement and also correlate with the numerical results.	

Altynshash Naimanova	SIMULATION OF THE SHOCK WAVE BOUNDARY LAYER INTERACTION IN FLAT CHANNEL WITH JET INJECTION
The multispecies supersonic gas flow in a planar channel with perpendicular jet injection is numerically simulated. The Favre-averaged Navier-Stokes equations coupled with the k-ω turbulence model are solved with using the forth order WENO-scheme. The simulation correctly captured the main flow features near the jet and the comparison with the experimental data shows a satisfactory agreements.The reflected shock wave, formed as a result of the interaction of a bow shock wave with the boundarylayer (SWBLI),	

reaches lower boundary layer behind the jet and interacts with them. The numerical experiments reveal shows that this shock/wave interaction causes an oscillation of the flow.The channel height variations show that with decrease of the height the mixing rate increased.

Roman Fursenko	Dynamics of Thermally Conjugated Combustion Waves Propagating in Inert Porous Media and Solid Energetic Material
Effect of thermal conjugation between the reaction wave propagating in a cylindrical energetic material and filtrational combustion wave in an inert porous medium surrounding this cylinder is numerically studied. Temporal evolution of the gas, solid energetic material and porous media temperature distributions, as well as the concentration profiles of the gas-phase combustible mixture and solid energetic were obtained. It was found that, depending on the chemical properties of solid energetic material, various combustion modes including independent propagation, connected propagation, supporting propagation, accelerating and retarding propagation of combustion waves can be realized. Numerical results demonstrate extension of the extinction limits of solid energetic by expense of heat support from the filtrational combustion wave.	

Evgeniy Dats	Features of filtration gas combustion inside a porous cylindrical pipe with axial gas flow
The filtration gas combustion in a porous tube with injection of a combustible mixture through the end surface of a porous cylindrical tube is theoretically studied. This scheme of filtration gas combustion can be used to create chemical reactors for non-contact heating of various materials to high temperatures. The samples under treatment can be placed inside a porous tube, the side surface of which is covered with quartz shells transparent for infrared radiation emitted by porous carcass. The outer surface of porous reactor is heat insulated. Radiation from the surface of the porous solid phase allows heating materials under treatment to high temperatures. The simulation of the filtration gas combustion was carried out in the framework of the two-temperature thermal-diffusion model. Numerical modeling allows to estimate the range of gas flow rates at which a stable combustion regime is observed, to find the temperature distribution in the gas and the porous body, and to evaluate the radiation fluxes inside the reactor. The influence of heat loss and the geometric characteristics of the reactor on the flame stabilization is studied.	

Taisia Miroshnichenko	Propagation of Combustion Wave in a Two-layer Solid Fuel System
The work is devoted to the study of the regimes of combustion wave propagation in a two-layer solid fuel system. The influence of thermodynamic parameters such as the rate of heat transfer and the rates of chemical reactions in each layer is analysed as well as the influence of the geometrical properties of the structure on the steady combustion process. It has been revealed that the rate of joint propagation of combustion waves increases along with an increase in the distance between the fronts with increase the ratio of the rates of chemical reactions. In addition, going ahead wave creates conditions for the appearance of super-adiabatic temperatures in the second wave. It is shown that an increase in the rate of heat transfer leads to a qualitatively similar drop in the rate of joint propagation of combustion waves at large and small ratios of the rates of chemical reactions in the layers.	

24.09.2019

Alexander Konnov	Laminar burning velocities and LIF measurements of NO formation in premixed flames of simple alcohols
The use of short aliphatic alcohols as additives to transportation fuels has been proven to sensibly reduce harmful pollutants, such as CO, HC and soot, while some inconsistencies among different studies were observed for nitric oxide (NO) emissions. To this end, it would be of particular interest to analyze the effect of alcohol structure on NO formation. In this study, the laser-induced fluorescence (LIF) technique was applied to measure quantitative NO concentration in the product zone of premixed flames of alcohols and air. Flames were stabilized on a heat-flux burner at 1 atm over the equivalence ratio range 0.7-1.4. The heat flux method yields laminar burning velocities and ensures a steady 1D structure of the flames. The laser power used resulted in fluorescence measurements in the so-called saturated regime to minimize quenching effects. Measurements were performed in the production zone at 10 mm above the burner plate. The method was verified by the measurements of NO concentration in premixed methane+air flames for which results could be compared with previous LIF and probe-sampling measurements. Methanol+air flames were stabilized at initial gas temperature of 318 K. Methane and methanol flames were modelled using five kinetic mechanisms from literature. While the thermal NO is well predicted by all the models, there is large variation between predictions of the prompt NO formation. New accurate measurements of the adiabatic laminar burning velocities and NO concentrations of ethanol, n-heptane and a mixture of them at initial gas temperature of 338 K are also reported. The results demonstrate similar trends as a function of equivalence ratio for the investigated fuels. The ethanol+air mixture shows higher burning velocities and lower NO concentrations than the other two mixtures. The burning velocities of these flames are accurately reproduced by the PoliMi detailed kinetic mechanism, however model predictions significantly deviate from the experiments for the prompt NO formation in rich flames. Burning velocity of the flames of propanol isomers were measured at initial gas temperature of 323 K. N-propanol has notably higher burning velocity than i-propanol, however, no appreciable differences were observed between the two isomers for the NO formation over entire range of equivalence ratios. A new detailed kinetic mechanism for propyl alcohols combustion is presented,	

and numerical simulations showed good agreement with experimental data both for the burning velocities and NO concentrations. These series of measurements are believed to be valuable data for validation of detailed kinetic models.

Alexander Mebel	Reaction Mechanisms and Rate Constants of PAH Growth
The presentation will overview results of quantum chemical calculations of potential energy surfaces combined with RRKM-Master Equation calculations of reaction rate constants, carried out in order to unravel reaction mechanisms of the growth of polycyclic aromatic hydrocarbons (PAHs) at temperatures and pressures relevant to combustion as well as to carbon-rich circumstellar environments and the interstellar medium. We will describe our recent efforts directed toward the development of a comprehensive mechanism of PAH growth and consider possible formation routes to three- and four-ring PAHs, such as anthracene, phenanthrene, helicene, triphenylene, etc., as well as the Hydrogen Abstraction aCetylene Addition (HACA) and Hydrogen Abstraction Vinylacetylene Addition (HAVA) growth mechanisms of larger PAHs.	

Valeriy Azyazov	Kinetic studies with High Temperature Chemical Micro-Reactor
A resistively-heated silicon carbide high-temperature ‘chemical reactor’ (micro-reactor) incorporated into a molecular beam apparatus operated with a Wiley-McLaren reflectron time-of-flight mass spectrometer (Re-TOF-MS) was employed for experimental studies of reactions involving hydrocarbons. Computational fluid dynamics (CFD) simulations and isothermal approximation were applied for the interpretation of experimental measurements Applying isothermal approximation allows the derivation of analytical relationships between the kinetic, gas flow, and geometrical parameters of the micro-reactor which, along with CFD simulations, accurately predict the experimental observations. Based on the obtained analytical relationships, a clear strategy for measuring rate coefficients of (pseudo-)first-order bimolecular and unimolecular reactions using the micro-reactor has been proposed.	

Ekaterina Mikheyeva	Experimental investigation of PAH growth in pyrolysis of benzene with biofuels additions
The PAH molecules are well-known precursors of soot particles. Diagnostics of the formation and growth of PAHs, as well as the modeling of the formation of the soot particles nucleus from large PAHs during the pyrolysis and combustion of hydrocarbons, is currently of interest. In this work, an experimental study of the growth of PAH and the subsequent formation of soot particles during the pyrolysis of benzene with the addition of biofuels: DME, butanol, and ethanol in a shock tube in the temperature range of 1000–2000 K and pressures of 3-5 atm was carried out. The LIF with the excitation wavelength of 266 nm was used for PAH measurements. The laser light extinction at a wavelength of 633 nm was used for observation of particle inception and soot volume fraction measurements. The LII was used for the measurements of soot particles sizes. The results of kinetic modeling of PAH growth from the gas phase are discussed.	

Lesbayev B.T.	FEATURES BURNING COAXIAL FLAMES
But in despite of numerous studies of combustion processes, the questions related to the formation mechanisms of final combustion products remain open up to now. At present, the studies related to the nucleation and growth of solid carbon product in flame indicate that the reaction routes on precursors formation of aromatic molecules, C3H3, C4H3, C4H5, C2H2, C3H2, C4H2иC4H4, are not universal for different types of fuels and are highly dependent on process conditions, which is determined the kinetics of active radicals of combustion process of OH, H, O, HO2, CH3, C2H, HCO, C2H3, ions and molecules. The composition, structure and properties of formed first aromatic molecules, their growth up to poly-aromatic combustion products in flame depends on composition and concentration of forming intermediate particles and aromatic precursors. By combining the compositions of intermediate components and density of aromatic precursors, it is possible to create the conditions are most favourable for the growth of poly-aromatic molecules. So, the various classes of hydrocarbons - iso - and normal paraffins, olefins, acetylenes, naphthenes (cyclic) and aromatic ones have individual features for the development of aromatic precursors and active radicals - agents on development of chain reaction of combustion and growth of aromatic rings, it seems effective the usage of combination of intermediate oxidation products of various types of hydrocarbons in order to obtain the aromatic molecules with required size. Fundamental studies of structures of such flames are practically unknown. The scientific novelty of the presented research is the experimental study of the features of the combustion of coaxial flames in order to control the processes of formation of combustion products in the combined reaction zone. In the proposed work, the process of coaxial combustion of ethanol with propane and benzene was studied and spectral analysis was used to study the composition of intermediate particles in height in the combined reaction zone of the coaxial flames under investigation.	

Viatcheslav Bykov	Model reduction of mechanisms of chemical kinetics: standard versus recently developed approaches
Modelling of chemical kinetics for computation of combustion processes have become complicated in terms of a number of variables and physical parameters involved. This fact and an exponential dependence of elementary reaction rates on the temperature due to the Arrhenius law lead to CPU time and memory storage demanding computations. In order to run computations of combustion processes in a reasonable CPU time, reduced kinetic models are needed and have been rapidly developed in recent years. The current talk is devoted to this challenging problem. Question how to perform model reduction avoiding difficulties and	

drawbacks of standard approaches will be in the focus of the talk. An approach to cope with this problem will be suggested and outlined, it is based on detailed study of a real system dimension in the system thermo-chemical state space. Two powerful approaches are incorporated: singular perturbations and invariant manifolds methods, which make the proposed method very efficient and attractive for model reduction leading to reliable and accurate models of chemical kinetics.

Toru Sugita	Study on low temperature methane reactions enhanced by dimethyl ether using a micro flow reactor with a controlled temperature profile

Initial-stage reactions of methane/dimethyl ether (DME) in low temperature was investigated by a micro flow reactor with a controlled temperature profile (MFR). DME was used as a radical initiator to enhance initial-stage reactions of methane. In this study, a stoichiometric mixture of methane/DME/air was employed at fuel blending ratio of 90/10 methane/DME. Flame observation experiments and CH2O-LIF measurements were performed for weak flames in MFR. 1-D MFR simulations with detailed chemical kinetic models were implemented to analyze the mechanism of interactions between methane and DME oxidations. A hot flame location of methane in MFR was shifted to lower temperature side by the addition of 10% DME. A cool flame was not observed in flame observation. CH2O-LIF, however, showed CH2O formation occurs from 600 K. Numerical analysis suggested that initial-stage reactions of methane be induced by OH radicals from DME oxidation.

Shintaro Takahashi	Unique oxidation characteristics of C1-C2 hydrofluorocarbon refrigerants examined by weak flames in a micro flow reactor with a controlled temperature profile

To assess the flammable risk of refrigerants, we examined the combustion and ignition characteristics of refrigerant R32 (CH2F2), R125 (C2HF5) and R410A (CH2F2/C2HF5) using a micro flow reactor with a controlled temperature profile. From experiments and computations, the reactivity decreased as the proportion of C2HF5 in the mixed fuels increase up to 50 wt%. When the proportion of C2HF5 exceeds 50 wt%, the reactivity increased with the increase of C2HF5. Analysis of flame structure and heat release per reaction of each fuel revealed that unreacted CO increased with the addition of C2HF5 and contributes greatly to the heat release at high temperature region, which implied that the reactivity of refrigerant depended on CO consumption.

Keisuke Kanayama	Formation of C0-C2 species and Benzene from Extremely Fuel-rich Combustion of CH4/air Mixtures using a Micro Flow Reactor with a Controlled Temperature Profile

Investigating formation of C0-C2 species and benzene from extremely fuel-rich combustion of methane at low temperature condition is highly required for further understanding in fuel reforming and formation of soot precursors. Species measurements of C0-C2 species and benzene were conducted using GC and GC-MS connected to a micro flow reactor with a controlled temperature profile (MFR). Equivalence ratio of CH4/air mixtures was varied over a range of 1.7-6.0, which is 15-38 mol% in fuel fraction. H2, O2, CH4, CO, CO2, C2H6, C2H4, C2H2 and benzene in burnt gases were measured at the exit of the reactor with the maximum wall temperature of 1300 K. In order to simulate species production in MFR system, computations using several detailed chemical kinetic models were also performed. Comparison between experimental and computational results indicated that modification of chemical kinetic model is necessary to acquire accurate prediction of C2H2 mole fraction.

Assel Beketaeva	SIMULATION OF THE SHOCK WAVE BOUNDARY LAYER INTERACTION IN FLAT CHANNEL WITH JET INJECTION

The multispecies supersonic gas flow in a planar channel with perpendicular jet injection is numerically simulated. The Favre-averaged Navier-Stokes equations coupled with the k-ω turbulence model are solved with using the forth order WENOscheme. The simulation correctly captured the main flow features near the jet and the comparison with the experimental data shows a satisfactory agreements. The reflected shock wave, formed as a result of the interaction of a bow shock wave with the boundarylayer (SWBLI), reaches lower boundary layer behind the jet and interacts with them. The numerical experiments reveal shows that this shock/wave interaction causes an oscillation of the flow.The channel height variations show that with decrease of the height the mixing rate increased.

Alina Ponomareva	A NEW DESIGN OF MICRO FLOW REACTOR OF SPIRAL TYPE

In this work, the laboratory-made setup was developed and constructed in the purpose to investigate different gases combustion behaviors. The main advantage of the new micro flow reactor construction is a spiral form that serves the mild temperature gradient in the reacting zone. Due to the mild temperature gradient the developed micro flow reactor has a higher resolution than available analogues. That can improve the experimental technique and results obtained. The constructed set-up was tested using a methane/air mixture. In the future it's planned to perform a comprehensive experimental, numerical and theoretical study of the nature, modes

and parameters of different gases combustions. The study was supported financially by the Ministry of Education and Science of Russian Federation (project RFMEFI58417X0031).

Anatoly Maznoy	Combustion synthesized radiant burners: state of the art.

Radiant burners show many advantages over the traditional free flame burners, such as the generation of intense IR fluxes, low NOx emission, stable combustion of fuels with substantially different burning velocity: bio-gases, syn-gases, hydrogen enricher methane, etc. The major component of a radiant burner is a gas permeable material taking part in heat exchange with high temperature flue gases. The potential of the method of self-propagating high-temperature synthesis for fabrication of intermetallic porous materials for radiant burners will be discussed in our presentation. Namely, two SHS modes are of interest: thermal explosion mode and self-propagating mode. The thermal explosion mode allows to synthesize fine porous materials with average pore size of about 10-100 microns. The self-propagating mode is used for obtaining coarse porous materials with pore size up to 2000 microns. Coarse porous alloys have been already tested for designing radiant burners of cylindrical shape. The cylindrical burners have shown a superior radiation efficiency in comparison with vast majority of other design radiant burners. In order to show the prospects of new burner for industrial application an overview of devices for IR flux generation will be presented.