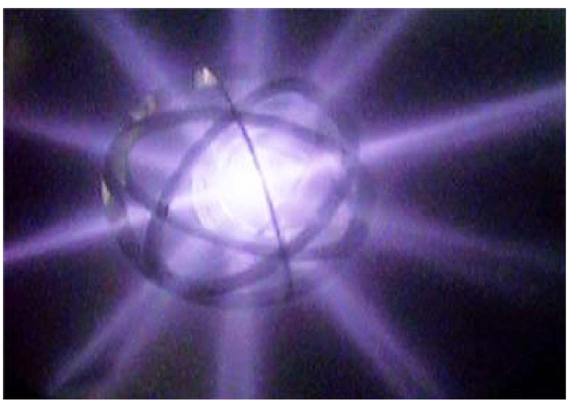
Abstract Book

21st US-Japan Workshop on Fusion Neutron Sources and Applications

17th -18th Dec. 2019

Kyoto University

Kyoto Japan



Dear Colleagues,

We are pleased to announce the Abstract book of the 21st US-Japan Workshop on Fusion Neutron Sources and Applications (formerly on Inertial Electrostatic Confinement Fusion Workshop), to be held at Kyoto University, Kyoto, Japan.

Website: http://www.atomic-energy.iae.kyoto-u.ac.jp/?page_id=3377&lang=en.

Place: http://www.kyoto-u.ac.jp/static/en/news_data/h/h1/news7/2010/100511_1.htm

The agenda: Please have a look at the attached file

Lab-tour:

09:30 Meeting at Obaku plaza Uji campus: 300 m from Obaku Station JR or Kehain

09:40 lab-tour starts with Helitron J facility, then DUET, and finally IEC facilities

12:00 Lunch at Obaku plaza cafeteria

13:10 Moving to the workshop venue

14:30 Registration at the workshop venue

15:00 Opening and sessions

19:30 the workshop dinner http://www.gion-hanasaki.com/english.html Presentation: 25 min(20 min and 5 for questions, session #4 only 20 min)

Poster size: Free size (please fix the poster on the second day 18th Dec from 9:30 and collect it 16:00

We are looking forward to welcoming you,

Please feel free to email me if you have any questions,

(bakr@iae.kyoto-u.ac.jp) (cell phone 08084963199)

21st US-Japan Workshop on Fusion Neutron Sources and Applications

17th -18th December 2019, Kyoto, Japan

Venue: Yoshidaizumidonocho, Sakyo Ward, Kyoto, 606-8301, Japan.

Registration deadline: Nov. 25th 2019

Website: http://www.atomic-energy.iae.kyoto-u.ac.jp/?page_id=3377&lang=en

Tentative Agenda for 21st US-Japan workshop on Fusion Neutron Source for Nuclear Assay and Applications
Yoshida-Izumidono, Yoshida-campus, Kyoto University, December 17-18, 2019

Tuesday, December 17					
9:30		Lab Tour at Uji-Campus			
12:00		Lunch (Obaku plaza cafetera)			
13:00		Transportation to Yoshida-Campus (using local shuttle bus)			
14:30		Registration at Yoshida-Campus			
15:00	15:10	Opening remarks			
			Satoshi Konishi	Kyoto University	
15:10	17:00	**Session 1 Chair: Yasushi Yamamoto**			
25 m			Gerald L. Kulcinski	University of Wisconsin, Madison	Neutron Production Facilities at the University of Wisconsin
25 m			Mahmoud Bakr	Kyoto University	Research activities and applications using IEC neutron source at Kyoto University
10 m			<Short Break>		
25 m			Joe Khachan	The University of Sydney	Progress in IEC research at the University of Sydney
25 m			Jun Hasegawa	Tokyo Institute of Technology	Recent Activities on IEC Fusion Studies at Tokyo Tech
17:00		Group Photo			
19:30		Workshop Dinner			

Wednesday, December 18					
9:30	10:45	**Session 2 Chair: Joe Khachan**			
25 m			Yasushi Yamamoto	Kansai University	Current status of IEC research at Kansai University 2019
25 m			John Santarius	University of Wisconsin, Madison	Plasma Physics and Related Issues for UW IEC Neutron Sources
25 m			Hodaka Osawa	Kansai University	Parallel operation of 9 spherical IECF devices
10:45	11:00	Coffee Break	and poster discussion		
11:00	12:15	**Session 3 Chair: Kai Masuda**			
25 m			Richard Bowden-Reid	The University of Sydney	The problem of anisotropic plasma conductivity in Polywell and magnetic virtual cathode systems
25 m			Hiroshi Okawa	Happy Science University	Development of linear-IEC equipment and its application to nitriding
25 m			Keisuke Mukai	Kyoto University	Two-dimensional evaluation of bred tritium using a compact neutron source and neutron imaging plate
12:15		Lunch			
13:30	14:50	**Session 4 Chair: Gerald L. Kulcinski**			
20 m			Nicholas Ranson	The University of Sydney	Ion divergence from a gridded inertial electrostatic confinement device
20 m			Yasuyuki Ogino	Kyoto University	Measurement of the Neutron Distribution with Cylindrical DD Neutron Source
14:10	14:50	Coffee Break	and poster discussion		
14:50	16:00	**Session 5 Chair: Satoshi Konishi**			
25 m			Hiroshi Horibe	KURITA Manufacturing Corp.	Developing of SiC Power Device Technology
25 m			Ross Radel (by Gerald)	Phoenix, LLC	Recent Progress on the Phoenix Accelerator-Based Intense Fusion Neutron Sources
		General Discussion & Closing, Student Award			
16:00		Adjourn			

Neutron Production Facilities at the University of Wisconsin-Madison

Gerald L. Kulcinski[a], John F. Santarius[a], Richard L. Bonomo[a], Marcos X. Navarro[a], Nolan C. van Rossum[b], Joshua B. Perry[a], and Aaron N. Fancher[c].

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[b]*Lockheed Martin Aeronautics, 1011 Lockheed Way, Palmdale, California, USA 93599*
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**Corresponding Author: Gerald L. Kulcinski, glkulcin@wisc.edu*

Over the past 25 years, scientists and engineers at the University of Wisconsin-Madison have constructed and operated 4 DD fusion neutron devices. The purpose of these devices ranges from the study of radiation damage in fusion materials, the production of short half-life radioisotopes, and the detection of clandestine weapons such as landmines, IEDs, fissionable material, and chemical weapons. This presentation will concentrate on the detection of chemical explosives using small (10 kg), low power (10 kW_e) neutron sources on small drones powered by beamed RF microwaves.

Use of Fusion Technology to Detect Chemical Based Weapons, Oral Presentation

Keywords: DD neutron, explosives detection, portable neutron sources.

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	☐ Yes ■ No

Research activities and applications using IEC neutron source at Kyoto University

Mahmoud Bakr[1,*], Kai Masuda[2], K, Mukai[1], S. Konishi[1]

[1] Institute of Advanced Energy Kyoto University, Kyoto, Japan
[2] Fusion Energy Directorate, National Institutes, (QST), Japan

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Abstract

Our group has been developing and operating inertial electrostatic confinement (IEC) fusion devices in both shapes, spherical and cylindrical structures. Due to the unique characteristics of the IEC fusion device, it has been combined with other technologies and proposed for divers of applications in Kyoto University. The present work focuses on the characterization and the prospective applications of the IEC device at Kyoto University. The next topics will be covered through the presentation:

1- The effect of the cathode material on the neutron yield from the IEC device. Two cathodes made from stainless steel (SS) and titanium (Ti) in buckyball shape, with 4 cm diameters, were used to perform the study. Experimental setup, conditions, and overview of the results will be presented and discussed in the meeting.

2- Development of a quantitative analysis of B-10 for boron neutron capture therapy (BNCT) based on IEC and tension metasatable fluid detector (TMFD) Systems. Proof of principle experiment has been performed using two different ^{10}B densities that originated from a chemical compound. Details of the proposed method combined with the experimental conditions and results will be discussed.

***Keywords**: IEC, BNCT, TMFD*

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	Yes ☒ No

Progress in IEC research at the University of Sydney

Joe Khachan[a*], Richard Bowden-Reid[a], Nicholas Ranson[a]

[a]*School of Physics, The University of Sydney, NSW 2006, Australia*

**Corresponding author : joe.khachan@sydney.edu.au*

The IEC work at the University of Sydney has mainly focused on diagnostics. A summary of past and present results will be given that include Doppler shift spectroscopy, laser-induced fluorescence, dusty plasmas, Langmuir probe, and neutron detection. These diagnostics have been applied to both gridded IEC and virtual cathode systems, such as those assumed to occur in a Polywell™ device.

The results presented will show that gridded IEC, which usually operates as abnormal glow discharge, produces a virtual anode at the center of the grid due to sheath effects rather than convergent ion flow. In addition, for grids that are at relatively low temperatures, it will be shown that a significant contribution to the fusion rate occurs at the cathode surface due to adsorbed target atoms.

Virtual cathodes, reported in some past experiments on magnetically shielded anode grids operating in the low beta range, will be shown to be a consequence of anisotropic plasma conductivity and its interaction with the potential at conducting boundaries rather than the trapping of electron clusters.

Keywords: Doppler shift spectroscopy, laser-induced fluorescence, surface fusion, Polywell, virtual cathode, the virtual anode.

Recent Activities on IEC Fusion Studies at Tokyo Tech

Hasegawa, J.*, Itagaki, T., Matsueda, Y. & Hotta, E.
hasegawa.j.aa@m.titech.ac.jp, Tokyo Institute of Technology, Japan
*lead presenter (email address)

An IEC device using linearly arranged hollow electrodes was developed recently at Tokyo Institute of Technology, and neutron generation experiments have so far been conducted. The advantage of the linear electrode arrangement is that both the cathode and the anodes are exposed and can be efficiently cooled by contact heat transfer. The developed IEC device is immersed in electrically insulating coolant liquid (Fluorinert) and operated while keeping the temperature of the outer wall at room temperature even during high power operation with several kilowatts. Neutron production rates (NPR) more than 10^6 n/s have so far been achieved under discharge conditions of ~100 kV and ~20 mA. On the other hand, as the input power increases, impurity particle emission from the anode surface becomes more remarkable due to the sputtering by high-energy particles, which makes the operation of the device unstable and limits the allowable input power. Thus, the design of the anode structure having robustness against the sputtering and erosion is the key to enhancing NPRs in the linear IEC device with higher input power.

In this study, we focused on the influence of the anode structure on the performance of the linear IEC device and conducted neutron generation experiments using four types of anodes having different structures. We found that the highest NPR was obtained when single cylindrical anodes were adopted. Inverse analysis of ionization rate distribution in the IEC device was also performed by combining the results of the Doppler spectroscopy of Balmer-α emission and Monte Carlo simulations of energetic particles moving in the device. The analyses showed that the ionization rate near the anode was enhanced when using the single cylindrical anodes, which is considered one of the causes of the NPR enhancement.

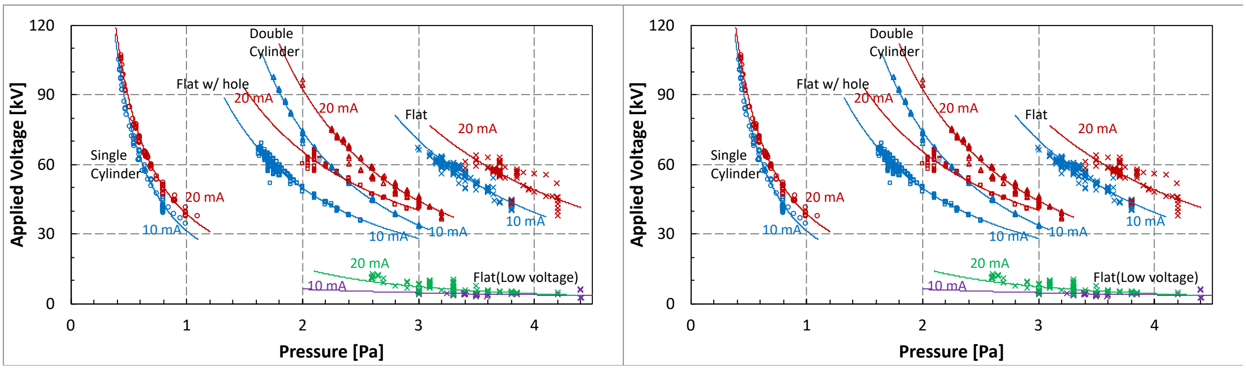

Figure 1. Dependencies of the discharge characteristics and neutron production rate of the linear IEC device on the anode structure.

Progresses of IEC research at Kansai University in 2019

Y. YAMAMOTO, H. OSAWA, A. INOUE, M. FUKUSHIMA, Y. MASHIMO,
K. NAKAMURA, T. OHTA, T. TSURUTANI, T. YAMANAKA,

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The IEC group at Kansai University has been working on the following issues since last year.

1. Examine and find a solution of problems that were found in the previous experiment for the next D-T burning experiment,
2. Creation of a planar neutron source by the parallel installation of small IEC electrodes

In this presentation, we will show an overview of our efforts.

In Task 1, first, we introduced Granville-Phillips® VQM (Vacuum Quality Monitor) based on the comments from last year's workshop, and are comparing its operating characteristics with QMS, and trying to measure ratio of gas mixture. From preliminary experiments, it is found that VQM has can obtain a sharp peak with a small FWHM and can accurately measure an element with a small mass number, but has the difficulty of detecting elements of 1% or less relative to the main peak as the amount of ions stored in the ion trap is limited by the device geometry.

We also found that isotope ratio of hydrogen and deuterium may be obtained using m/z = 41~42 in addition to estimation using m/z = 29~30 which we reported pervious years from mass scan results of QMS. We have been carried out literature searches of this phenomenon, and found that it may be explained by “mass spectrometry method using chemical ionization” used in the field of analytical chemistry.

In parallel with these, experimental equipment similar to that used at Osaka University is under construction at Kansai University to prepare for experiments and verify discharge characteristics. It is planning to start a discharge experiment.

In Task 2, we expanded from 2x2 configuration to 3x3 configuration in this year, and measured pressure-voltage discharge characteristics using spherical electrodes. Fabrication of rectangular electrodes using guide frames made by a 3D printer is underway.

Plasma Physics and Related Issues for UW-Madison IEC Neutron Sources

John F. Santarius,[a] Gerald L. Kulcinski,[a] Gilbert A. Emmert,[a] Richard L. Bonomo,[a]
Marcos X. Navarro, [a] Nolan C. van Rossum,[b] Joshua B. Perry,[a] and Aaron N. Fancher[c]

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* *Corresponding author: santarius@engr.wisc.edu*

During 25 years of UW-Madison Inertial-Electrostatic Confinement (IEC) Fusion Laboratory operation, many plasma physics issues have arisen, and our understanding has evolved. This talk will discuss the present understanding of several plasma physics and related issues for IEC neutron sources in general and the UW-Madison IEC neutron sources in particular:

- Similarity of the neutron production rate experimental performance in the LUNA linear IEC and HOMER spherical IEC devices when analyzed as consisting of individual line elements
- LUNA and HOMER chamber hot spots
- VICTOR code shortfall in neutron production rate predictions by a factor of approximately 8 compared to HOMER and LUNA experimental measurements
- The use of Principal Component Analysis (PCA) for identifying highly enriched uranium (HEU) and other clandestine materials using neutron and gamma signals patterned in space and time

Keywords: Plasma physics, Neutron sources, Principal Component Analysis, Linear IEC, Spherical IEC

Prefer oral presentation

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	□ Yes ☑ No

Parallel operation of 9 IEC devices

H. Osawa, S. Aoyagi, Y. Kokubu, S. Hagita, R. Shimada, T. Turutani, K. Nakamura and Y. Yamamoto

Faculty of Engineering Science, Kansai University. Yamate-cho, Suita-shi, Osaka, 564-8680, Japan. osawa@kansai-u.ac.jp

There were two ways to increase the neutron production rate of an IEC device. One was to increase the neutron output of a single IEC device. Another method was to increase the number of IEC devices that operate simultaneously. The research group at Kansai University had conducted parallel operation experiments of four cubic IEC devices, which sides were 8cm each. As a result, we obtained almost four times of neutron production rate than that of a single operation. In addition, we confirmed the uniformity of the neutron ray on the remote plate

We will give a presentation on the results of increasing the number of these cubic electrodes to nine and the state of the discharge. When the number of cubic IEC device was increased to 9, the discharge became slightly unstable. Therefore, we also did experiments with nine conventional small spherical electrodes (anode diameter 8 cm, cathode 3 cm). We will talk on the comparison of these discharge characteristics with cubic and spherical IEC devices.

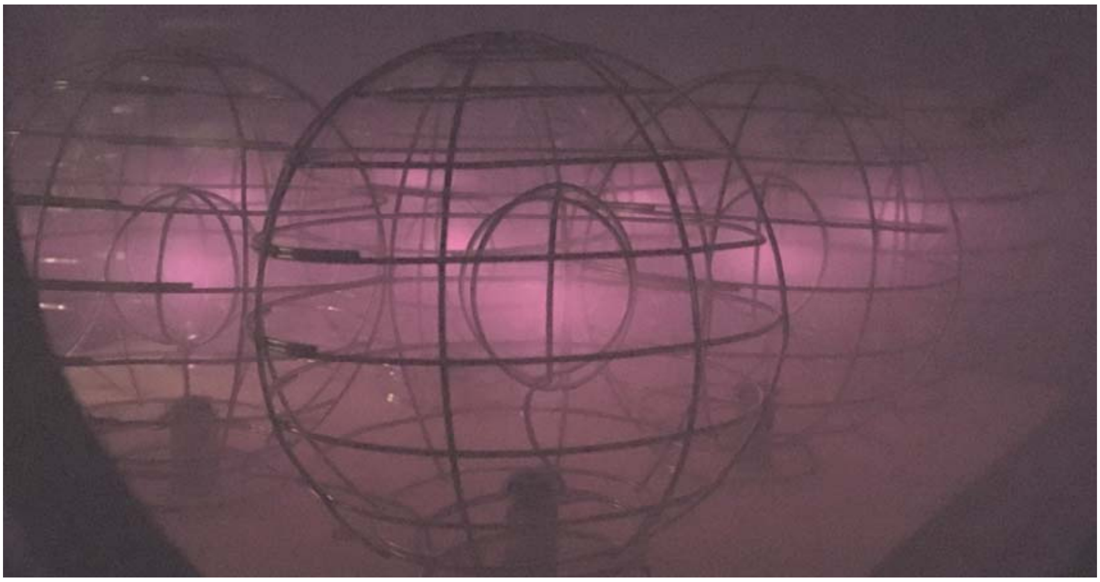

Fig. discharge photo of nine spherical IEC devices

The problem of anisotropic plasma conductivity in magnetically virtual cathode (Polywell) devices

Richard Bowden-Reid[a*]

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**Corresponding author : richard.bowden-reid@sydney.edu.au*

Magnetically confined virtual cathode (MCVC) machines use magnetic fields to trap a population of electrons such that the resulting space charge forms an electrostatic potential well for use in IEC fusion. The talk will describe the most recent MCVC device built at The University of Sydney and outline the results of experimental studies.

The experimental results were further explored computationally by modeling the MCVC plasma as an anisotropic, inhomogeneous conductor. The simulations were found to be in good agreement with the most recent experimental results, as well as those obtained in earlier Polywell machines. It will be shown that plasma anisotropy in a magnetic field may result in electric potential gradients that may be misinterpreted by researchers as virtual cathodes arising from the confinement of a negative space charge.

Keywords: Virtual Cathode, Polywell, conductivity

~~**Do you wish to apply to student award?**~~ ~~Student award will be given for the best student presentations at the workshop.~~	~~☐ Yes ☐ No~~

Development of linear-IEC equipment and its application to nitriding

Koki Narimatsu[a], Yawara Shina [a], Shiki Sato[a], Tomoki Kaneko[a], Daigo Kashiwabara[a]
Tetsuya Akitsu[a,b], Hiroshi Okawa[a*]

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[b]*University of Yamanashi, Takeda 4, Kofu, Yamanashi-Pref. 400-8511, Japan*

* *Corresponding author: hiroshi-okawa@happy-scinece-science.university*

An Inertial Electrostatic Confinement Fusion (IECF) device has been developed in a unique configuration, linear alignment aiming the long-time operation. Each part of the device is improved in terms of temperature control, and in addition, ion temperature and fusion reaction rate were calculated from plasma spectroscopy. The experimental result indicated the feasibility of overcoming the energy threshold of the prospected D-D fusion reaction. An engineering spinning out was demonstrated: plasma nitriding, taking advantage of the characteristics of IEC, resulting in the surface hardening of the metallic material.

Keywords: linear-IEC, nitriding

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	☑ Yes ☐ No

Two-dimensional evaluation of bred tritium using a compact neutron source and neutron imaging plate

Keisuke Mukai[1], Yasuyuki Ogino[2], Juro Yagi[1], Satoshi Konishi[1]

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Tritium breeding performance of a fusion blanket is a key parameter for the self-sufficient fueling of a fusion reactor, and thus designed to validate the performance of a neutronics experiment. Measuring the 2-D distribution of bred tritium is challenging via conventional methods such as gamma-ray counting from an irradiated lithium sample using a liquid scintillation counter (LSC) and a single-crystal diamond detector with a thin ^{6}LiF film, because they are point detectors which require many measurements. In this article, 2-D distribution of the low quantity produced tritium was evaluated with a neutron imaging plate (NIP) with a Gd convertor by estimating the loss of neutrons via a capture reaction by Li. Deuterium–deuterium (DD) fusion neutrons were generated using a compact fusion device at an average neutron production rate of 1.5×10^{5} n/s by applying high voltages. A neutron image with "shadows" projected by thermal neutron capture reactions of ^{6}Li(n, α) and ^{10}B(n, α) was successfully obtained. The experimentally evaluated values were confirmed to be consistent with the total number of capture reactions calculated using a neutron transport code. The results suggest that the approach could be a facile method for the 2-D evaluation of bred tritium.

Neutron imaging, neutron generator, fusion blanket, tritium

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Ion divergence from a gridded inertial electrostatic confinement device

Nicholas Ranson[a], Joe Khachan[a]
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IEC discharges are currently understood in scientific literature to form a positive space charge at the cathode center by the focus of positive ions originating from the main bulk of the plasma between the cathode and anode. The talk will describe the recent, and past experimental and analytical works from The University of Sydney and other institutions that show ion motion in IEC discharges and similar Hollow Cathode Discharges (HCDs) are in fact diverging from the cathode center, contrary to the accepted ion focus model.

Ion flow direction has been characterized to be divergent from the cathode center for HCDs operating at the same discharge parameters as conventional spherical grid IEC devices. This ion divergence was successfully modeled to a first approximation as ambipolar diffusion. Laser Induced Fluorescence (LIF) spectroscopy was performed upon a hybrid two ring IEC/HCD cathode under the abnormal glow discharge regime, revealing similar ion divergence as previously discovered. A discharge model, including the cathode sheath is presented that forms a virtual anode able to replicate the measured spatial ion velocity profile. An argument is made comparing the discharge characteristics of the two-ring device and a spherical IEC grid with supporting evidence from recent Doppler spectroscopic measurements.

Keywords: Ambipolar diffusion, hollow cathode discharge, ion focus model, laser induced fluorescence, cathode sheath modelling, virtual anode

Measurement of the Neutron Distribution with Cylindrical DD Neutron Source

Yasuyuki Ogino[a*], Keisuke Mukai[b], Juro Yagi[b], and Satoshi Konishi[b]

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Measurement of neutrons, especially the distribution and the energy spectrum, is required for evaluating the environment inside the blanket of a fusion reactor. The neutron distribution can be obtained by the computation of neutron transport such as MCNP, while the discrepancy between the computation and the actual condition would be unavoidable. In this study, the neutrons generated by the compact discharge-type deuterium-deuterium fusion device was measured by means of activation materials. The Au wire, In, and Dy foils were employed as targets. The irradiation target was surrounded by polyethylene blocks in order to moderate neutrons and to activate materials easily. After irradiation of neutrons, gamma-rays, and beta-rays emitted to an imaging plate, which is sensitive to radiations, and is possible to measure the distribution of radiations. Experimental results were compared with the computations by MCNP for the neutron transport and D-CHAIN for the activation analysis. This result suggests the feasibility of measuring a neutron distribution two or three-dimensionally.

Keywords: blanket, imaging plate, MCNP, DD fusion device

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	☒ Yes ☐ No

Developing of SiC Power Device Technology

Hiroshi Horibe

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Several years ago, IEC workshop in Kyoto I presented about the power device of SiC. At that time, I gave an Introduction to SiC. So far, the SiC power device has a lot of advantages and better characteristics compared with the current Si power devices IGBT, such as:

1. High frequency is 10 times higher than Si device IGBT.
2. The switch on-resistance is comparably low.
3. It can be run up to 200 C, so smaller heat think can be used.

The application of SiC has been spread in many industrial pieces of equipment. Recently, SiC power devices have been used not only in high voltage power supplies but also for cars, Trains, factory automation, motor control technologies, etc.

I will cover some of these technologies through my presentation and give brief introductions to our company products.

Do you wish to apply for student award? Student award will be given for the best student presentations at the workshop.	☐ Yes ☑ No

Recent Progress on the Phoenix Accelerator-Based Intense Fusion Neutron Sources

Ross Radel, Tye Gribb, Arne Kobernik, Chris Seyfert, Logan Campbell, and Preston Barrows

Phoenix, LLC: 2555 Industrial Drive, Madison, WI, 53713, Radel@PhoenixWI.com

Phoenix, LLC (formerly Phoenix Nuclear Labs) has developed a full line of accelerator-based neutron generators. This presentation describes the highest steady-state yield DD fusion-based system for materials testing in the World. This device utilizes a microwave ion source (MWS), 300kV DC accelerator, magnetic solenoid focus element, differential pumping system, and gaseous deuterium target to achieve DD neutron yields of $5x10^{11}$ n/s. Lower-yield variations of the device have been built using variable voltages and a solid titanium target. Testing of a DT version of the gas target system has been completed with measured neutron yields as high as $4.6x10^{13}$ n/s.

PNL has delivered a number of systems to government and commercial customers and has identified a number of longer-term commercial applications for this high-yield neutron generator. These include medical isotope production, neutron radiography, active interrogation for explosives and SNM detection, and Cf-252 replacement. Most applications require the development of specialized moderator assemblies and fixtures to meet customer requirements.

This state-of-the-art neutron generator technology is essential for many applications of critical global importance including neutron radiography, medical isotope production, detection of explosives and nuclear material, materials characterization, and others. The presentation will discuss these applications and recent progress made on the base accelerator technology.

Phoenix has deployed accelerator-based neutron generators for several applications, including medical isotope production (in conjunction with SHINE Medical Technologies), neutron radiography, neutron detector calibration, nuclear fuel quality assurance, and explosives and SNM detection, all of which are unique in their own technique of non-destructive testing. Of particular interest is neutron radiography, which is a very useful non-destructive imaging technique that aims to identify defects in materials where X-ray, ultrasound, Eddy-current testing, etc. will not suffice due to limiting densities, material composition and surface imperfections. Phoenix's goal is to use its technology to acquire high-quality neutron radiographs, in a duration comparable to a traditional nuclear reactor, without the heavy regulatory burdens and high construction and operational costs.

Nuclear Materials Test Facilities, Oral Presentation.

Keywords: neutrons, radiation damage, tritium, materials test facilities.

Do you wish to apply to student award? Student award will be given for the best student presentations at the workshop.	☐ Yes ■ No

Experiments on nine spherical anodes

Ryuju Shimada, Takumi Tsurutani, Kazuki Nakamura, Hodaka Osawa
and Yasushi Yamamoto

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We are studying small parallel IEC for applications of portable neutron sources. Last year, the performance of cubic anodes was researched. However, there was a problem that the discharge was difficult to stabilize. Therefore, in this year, the shape of the anode was returned sphere for stable discharge. The anode had a diameter of 80 mm and was made of stainless steel. The cathode was Mo wire with a diameter of 30 mm. The experiment was conducted at the discharge voltage of 20 kV, at 22.5 mA (2.5 mA for each cathode), and at the gas pressure of 1.9Pa. In addition, the anodes were fixed in order to prevent the anodes' moving due to the high voltage and to keep the distance between the cathode and the anode. 3D printers are used to make uniform cubic anode. The details of this experiment will be shown in the poster session.

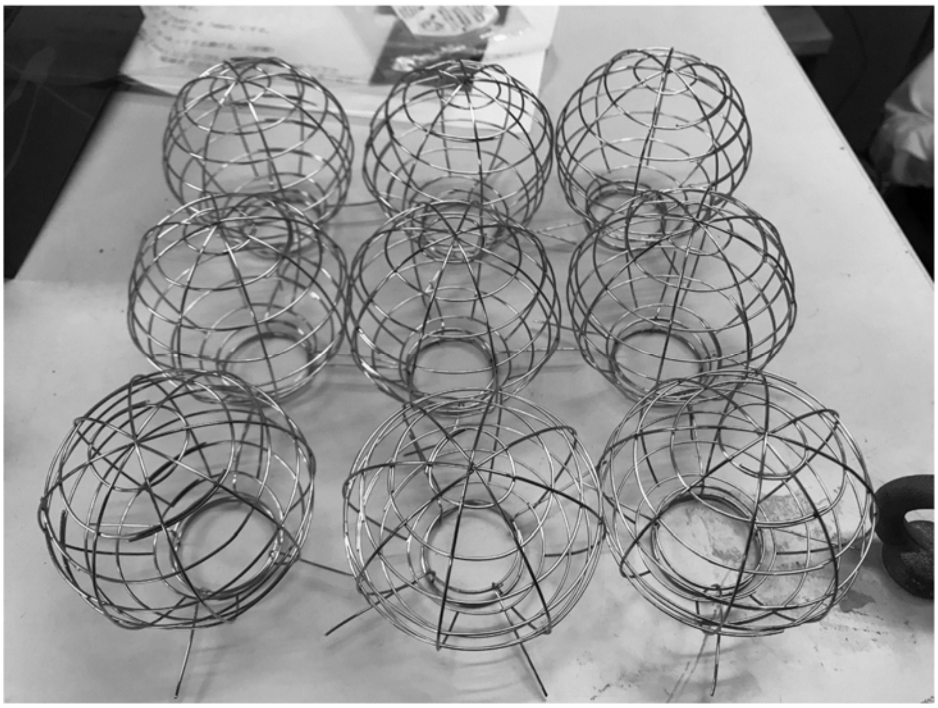

Fig. Nine wire anodes

Comparison of gas component analysis on H_2 and D_2

Teppei Ohta, Akira Inoue, Tomoki Yamanaka, Masahiro Fukushima, Yuki Mashimo, Hodaka Osawa, and Yasushi Yamamoto

Faculty of Engineering Science, Kansai Univ., Yamate, Suita, Osaka, 564-8680, Japan

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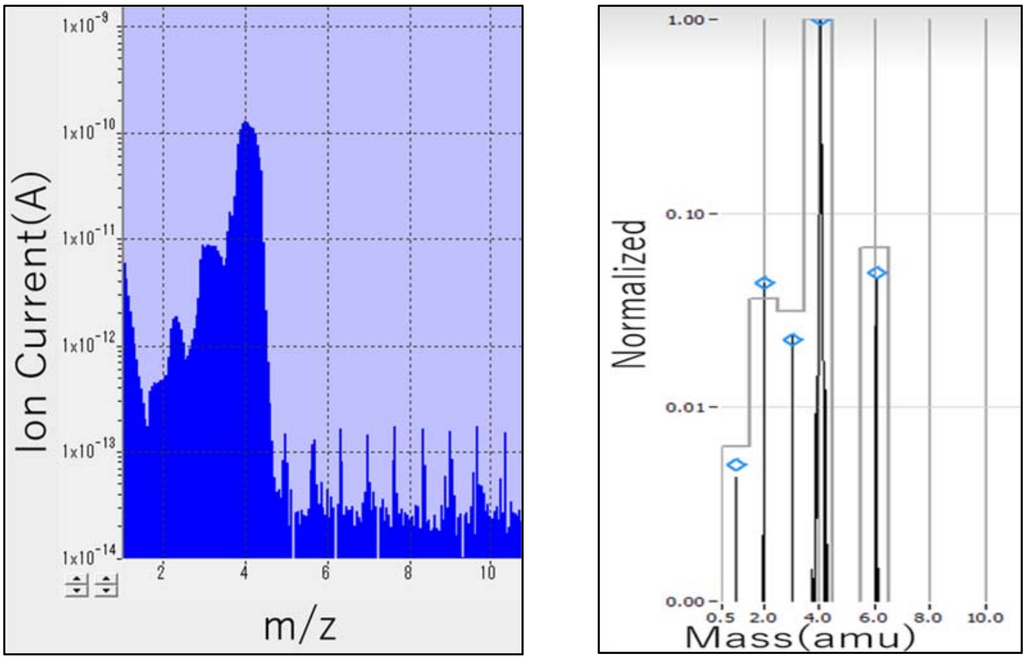
During the D-T discharge experiment at Osaka University in 2015, deuterium and tritium gas were occluded in a non-evaporable getter pump at a ratio of D: T = 93: 7. However, the neutron production rate was lower than expected. It was considered that enough D-T mixed gas was not supplied from the getter pump into the chamber at the assumed gas amount and ratio, because there was hydrogen from moisture remaining on the inner wall. Analysis of gas components was necessary for confirming whether the assumed gas could be supplied.

Conventionally, the gas components of the hydrogen isotopes were analyzed by Quadrupole Mass Spectrometer(QMS). However, QMS is unreliable at low (under 4) mass-to-charge ratios due to the influence of zero blasting. In this study, we used Vacuum Quality Monitor (VQM) for analysis. VQM can observe the peaks even when the mass-to-charge ratio is low. It is necessary to reduce the gas pressure below 10^{-5} Torr, which VQM can work. We installed an orifice plate to make differential pressure. In my presentation, I will compare the measurement results of VQM and QMS when hydrogen gas or deuterium gas is supplied into the IEC device.



(a)QMS (b)VQM

Fig.1 D_2 gas supply experiment result

Estimation of Hydrogen Isotope Ratio in discharge gas

-- Chemical Ionization Method in Mass Spectrometry—

Tomoki YAMANAKA, Masahiro FUKUSHIMA, Teppei OHTA, Yuki MASHIMO,
Akira INOUE, Shota ISHINO, Hodaka OSAWA, Yasushi Yamamoto
Faculty of Engineering Science, Kansai University,
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The results of D-T burning experiments conducted in 2015 show that (1) measured neutron reaction rate is much smaller than calculated from T ratio of prepared gas, (2) it is difficult to estimate D-T ratio from QMS scan results. Thus we have been working on improvement of measurement method of hydrogen isotope ratio.

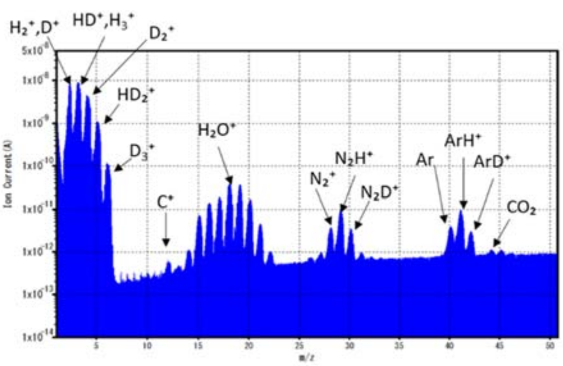
From the results obtained from H2, D2 gas supply experiments, we have reported followings at 2017, 2018 meetings,

- ✓ With the supply of two gases, H2 and D2, the H and D ratio can be estimated from the abundance ratio of DDH (m/z = 5) and DDD (m/z = 6),
- ✓ The measured value of m/z = 29, 30 is correlated with the ratio of DDH, DDD,
- ✓ A prediction formula can be made for the H and D release characteristics from the getter material.

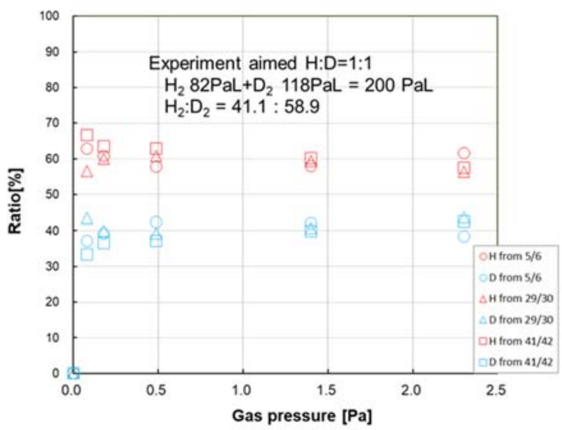
Also as the signal of N_2 (m/z = 28) decreases with the increase m/z = 29, 30, it is estimated that these signals indicate N_2H and N_2D. But we were not able to show why there is correlated to gas ratio.

It is also found that not only m/z = 29 ~ 30, but also signal of m/z = 41~42 shows the same phenomenon and correlates with m/z = 5, 6 in this year's experiments.

We have made literature survey of these phenomenon, and come to a “quadrupole mass spectrometry method using chemical ionization by protonation” in the field of analytical chemistry. In analytical chemistry, methane is mainly used as the proton source, but the paper said hydrogen is also possible. Although the pressure range is about two orders of magnitude lower, but it is considered that the conditions for protonation of nitrogen are satisfied.



An example of QMS mass scan result



H_2, D_2 ratio estimation result

Presentation files

Abstract book of the workshop and presentation slides are distributed within the workshop participants.

The files will be uploaded to Kyoto University's file uploader after the workshop.

Please access from the following link or QR code.

Download link

https://fsv.iimc.kyoto-u.ac.jp/public/INywwAaXOUfAJYwBWfhuyc793dcljw2LeG2Gw2LCCfup

Password: ********

It is noted the online folder is accessed by participants who know the URL and password.

The online-folder is accessible until 30th Jan. 2020.

Best regards,

The workshop organizing team