Prepare for the D-T Burning in IECF – relocation, remote operation, and tritium handling –

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What we did since last meeting

at Kansai University

• Improve high voltage holding
  baking / outgasing of chamber / high voltage feedthrough
  → 45kV, 50mA discharge (Hydrogen / Deuterium)
  add a stabilizing resistor / corona ring
  → 60kV, 20mA, 0.63Pa (Hydrogen) discharge
• Preliminary D₂ discharge and neutron measurement
  maximum 8.76x10⁵ n/s at 45kV-50mA, 1.0Pa
• Make and test prototype of getter pump
• Make and test tritium recovery system

at Osaka University

• Relocation of IECF device to the OKTAVIAN main hall
• Remote operation
• Moving into the heavy irradiation room
Contents

- Intense 14MeV Neutron Source Facility (OKTAVIAN)
- Restrictions
- Relocation of IECF device to the OKTAVIAN main hall
- Remote operation
- Moving into the heavy irradiation room
  - Weekly experiment schedule
- Getter pump system, water bubbler (Tritium handling)
Facility?

The IEC facility at IAE does not have a license to use isotope. Isotope laboratory in main building has a license to use tritium but does not have neutron shield.

? what we can do

(1) As tritium less than 1GBq is not considered isotope, it is possible to make experiment with keeping total inventory in the facility less than 1GBq for proof-of-principle D-T IEC experiment. → university code does not allow

(2) find out some place which has both license.

→ OKTAVIAN facility at Osaka University.

restriction no license for gaseous tritium
tritium gas must not be detected
entrance size 1m x 1.8m
Subcritical assembly Building (OKTAVIAN Facility)

- **Main hall**
- **Heavy irradiation room**
- **Control room**
- **DC beam line**
- **Pulse beam line**
- **Dorr way**

- **Nuclear Fuel**
- **Am-Be**
- \(~10^7\) n/sec

- **Dimensions**:
  - 31.5m
  - 17.0m
OKTAVIAN Facility Photographs (1)

- Cockroft-Walton's apparatus
- Accelerator system
- Control room
OKTAVIAN Facility Photographs (2)

Pulse beam line

Design : $1 \times 10^9$ n/sec (20µA)
- pulse width 2nsec
- max repetition 2MHz
Current : $5 \times 10^8$ n/sec (5µA)
- pulse width 3nsec

Rotating target with water cooling
Replaced by fixed target now.

DC beam line

Design : $3 \times 10^{12}$ n/sec (20mA)
Current : $1 \times 10^{11}$ n/sec (1mA)
due to target problems
Restrictions for the IECF experiments

• The facility does not have license for gaseous tritium
  ✓ Tritium must be absorbed in metal for bring in/out of the facility.  
    → non-evaporate getter pump with temperature control
      for hydrogen pressure
  ✓ Tritium density in the facility must be kept normal level as a facility
    with sealed radiation sources ( < 70 Bq/cc )
    → IEC discharge with getter pump
      Tritium recovery device
      purge gas line, oxidation catalyst and water bubbler

• Entry to the experimental area is limited during neutron production
  ✓ A few minutes entry to Main hall
  ✓ No entry into the heavy irradiation room
    → remote operation using KVM extender

• Machine time
Schematics of experimental device

- Display
- MFC1
- MFC2
- High voltage power supply
- High voltage power supply
- Neutron measurement
- chiller
- Diaphragm Pump
- TMP
- Purge gas
- MFC
- CuO Catalyst
- Water bubbler
- Heater
- Stabilizing Resistor
- High Voltage feed through
- Web camera
- Valve
- VCR
- D2/T2 Gas cylinder
- Heater
- D2 Gas Cylinder
- MFC
- Regulator
- Ion pump
- 3He Neutron Detector
Experimental setup at Kansai Univ.

Power Supply
125kV-60mA

High voltage line

Vacuum chamber

He counter

Bubbler unit

D²/T² supply

Pumping & Gas feed unit

Main Unit
Relocation of the IECF device to Mail Hall
February 27, 2014 ~

- Relocation
- Chiller replacement for high power experiments
- Install and test remote operation based on KVM extender + USB cameras
- $^3$He neutron counter calibration using Am-Be source
- D-D experiments
- Install getter pump
Relocation of the IECF device to Mail Hall
February 27, 2014 ~
Remote Operation

Remote PC operation

Emergency power cutoff switch

Labview panels

- Mass flow
- Getter PS

Camera views

- Plasma
- getter PS
- Power supply
- Vacuum gage

QMS

MCA
Calibration using Am-Be source
D-D operations

• Preliminary experiments at Kansai Univ., we got $7.0 \times 10^5$ n/sec neutron production at 45-kV, 50 mA discharge.

• D-D discharge experiments at OKTAVIAN facility, $8.8 \times 10^5$ n/sec was obtained at 60-kV, 10mA discharge.

→ detail of the results will be presented by Mr. Miyamoto at Poster session.
Installation to the heavy irradiation room

First trial installation and removal of IECF system to the heavy irradiation room was carried out September 22, 2014.
Installation to the heavy irradiation room

Power supply/control PC rack was also moved to just beside the wall
IECF system in the heavy irradiation room

- Upper through hole
- High voltage Line
- Current return Line
- Cooling water
- Ground plate
- Control/measurement lines
- Floor tunnel
IECF system in the heavy irradiation room

First Discharge with D₂ gas
at 1Pa, 10kV, 10mA
2014/9/22 ~ PM 7:00
Removal from the room

Since strong neutron radiation from OKTAVIAN operation might damage electronic circuits in QMS, IG, TMP etc., and make detectable activation of materials which will be problem for relocation from the facility to Kansai University, we are requested to remove all device after each machine time.
Weekly schedule of the experiment

Monday :
  Moving : the IECF/Vacuum system rack into the heavy irradiation room
  Connections : water, electrical, vacuum system
  Test 1 : vacuum, high voltage holding
  Test 2 : neutron measurements, reference operation with $D_2$ gas

Tuesday, Wednesday :
  Move pump/gas rack to adjoining room, close plug door
  D-T Experiments

Thursday :
  Install pump/gas rack, tritium collection system
  Discharge clearing of the chamber and tritium collection

Friday :
  Removal from the heavy irradiation room
How much tritium do we need to use?

• Gas quantity needed for experiments
  maximum pressure 4 Pa
  chamber volume \( \sim 10 \text{ l} \)
  \[ \Rightarrow 40 \text{ Pa} \cdot \text{l} = 1.76 \times 10^{-5} \text{ mol} = 0.395 \text{ SCCM} \]

• If tritium ratio is 10% (first trial),
  quantity of the tritium is
  \[ 1.76 \times 10^{-6} [\text{mol}] = 1.056 \times 10^{-5} [\text{g}] = 3.8 \times 10^9 [\text{Bq}] \]

• If tritium ratio is 50% (goal),
  quantity of the tritium is
  \[ 8.8 \times 10^{-6} [\text{mol}] = 5.28 \times 10^{-5} [\text{g}] = 19.0 \times 10^9 [\text{Bq}] \]
Consideration about a gas supply system

• In order to use tritium, IECF operation with sealed vessel is indispensable.
• In the IECF system developed for the landmine detection,
  – SASE Getter SORB-AC GP-50 cartridge pump was adopted for both evacuation of impurity gas and deuterium supply. Deuterium pressure was controlled by temperature of the getter material.
  – The inventor of deuterium gas in the GP-50 pump is about \(20\text{Torr} \cdot \frac{l}{g} \times 32 \text{ g} = 640\text{Torr} \cdot l = 8.5 \times 10^4 \text{ Pa} \cdot l = 0.04 \text{ mol},\)
  – which is more than 2,000 times larger than maximum required \(D_2\) quantity for discharge.
• To keep tritium use as low as possible, we need to reduce inventor in the getter material.
  – We try to make small pump using SASE Getter St 707 strips St707/CTS/NI/8D (amount of getter material is \(3.6\text{g/m}\)) with current heating
Hydrogen supply/recover system using St.707 strip

• Strip length calculation

Pressure 4 Pa
Volume 10 l

Hydrogen density in St.707
7 Torr·l/g = 931 Pa·l/g

\[ \text{required amount of the alloy} \]
\[ \frac{4 \times 10}{931} = 0.0429 \text{ [g]} \]

As strip includes 3.6 g alloy/m
\[ \frac{0.0429}{3.6} = 0.0119 \text{ [m]} \]

\~12 cm of the strip is required
First trial production

Current flow
St.707 strip
feedthrough
Since deuterium density in the getter material changes with initial packing pressure, the equilibrium pressure over temperature (heating current) differs. Result is within what is expected, and has reproducible.
Characteristics  ultimate pressure

Ultimate pressure after deuterium/tritium is absorbed into the getter is important to determine how much gas is remained in the chamber. We measured it for different loading amount of deuterium gas at room temperature.

<table>
<thead>
<tr>
<th>Loading pressure</th>
<th>Ultimate pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (all)</td>
<td>$3.25 \times 10^{-3}$ [Pa]</td>
</tr>
<tr>
<td>5.0 [Pa]</td>
<td>$2.25 \times 10^{-3}$ [Pa]</td>
</tr>
<tr>
<td>3.0 [Pa]</td>
<td>$2.15 \times 10^{-3}$ [Pa]</td>
</tr>
</tbody>
</table>

Values are readout of cold cathode gage

It is about 1/1000 of the loading gas pressure.
Isotope effect?

Deuterium case shows higher equilibrium pressure than that of hydrogen case for same heating power.

H₂, D₂, T₂の常温での変化吸収量
井上直哉他, Zr-V-Feゲッターの活性化過程及び水素同位体の吸蔵—脱離と同位体効果、富山大水トリチウム科学センター研究報告 3, 1983.
Comparison of discharge characteristics

Discharge voltage dependence on gas pressure with getter pump is same as that with TMP exhaust. Impurities are not problem with a small getter pump.
Second trial with St.172 sintered porous getter

Since resistivity of St.707 strip (St.707/CTS/NI/8D) is small, it requires large current at low voltage (0.8V-44A) to heat.

This high current requires large feedthrough, thus we try to use St.172 Sintered porous Getter (St.172/HI/7.5-7). It is made of St. 707 alloy and includes heater.

Dimension is 7.5mm diameter x 7mm high, amount of getter material 775 mg.
Partial pressure measurement during absorption/desorption of $D_2$ gas

Absorption 1.0A
heat 3.48A
absorption 1.0A

Deuterium
Hydrogen
Mixed gas operation & problem

• Why
  D-T burning experiment will start from low tritium ratio and increase ratio to deuterium : tritium = 50% : 50%.
  When we asked prof. Hatano about mixed gas supply, he told us it takes a few month to prepare new mixture, and currently available mixture is $H_2:D_2:T_2 = 82\%:13.3\%:4.7\%$.

• Experiments with $H_2:D_2=4:1$ mixture gas
  We made experiments with hydrogen / deuterium gas mixture gas, to investigate characteristics of discharge, neutron production et. al.
  $9.5 \times 10^3 \text{ n/sec at } 45\text{kV, 10mA, 0.43 Pa (readout)}$
  QMS measurement shows mixture ratio changes when total pressure is changed (getter temperature is changed).
  add more $D_2$
  $2.5 \times 10^4 \text{ n/sec at } 55\text{kV, 10mA, } D_2 \text{ ratio is about } 10\%$
Discharge voltage, Mixture ratio vs. Gas pressure

2014/9/9  H₂ 3.8Pa + D₂ 0.83Pa
Equilibrium pressure of H$_2$ is a function of the H$_2$ concentration in the getter material. Equilibrium pressure of H$_2$, D$_2$, T$_2$ is depended on the concentration of each gas in getter material, thus ratio of H$_2$, D$_2$, T$_2$ is not constant and changes with temperature of the getter material.
Final design of getter pump

Ceramtec 8878-07-CF

CF34 flange

St.172 Sinterd porous Ge
(St.172/HI/7.5-7)
(getter St.707 0.72g)

SS-4BK-TW × 2

SS-4-VCR-3-4MTW
+ SS-4-VCR-1
差し込み溶接

3/8” pipe
突き合わせ溶接

~300

~74
7.2 40 7
12.7 60 8 12
42.7 10 42.7−α 33.3
Getter pump unit
Summary

Preparations for proof-of-principle D-T burning experiments have been made in following area.

• Improve high voltage holding problem, the IECF device is able to operate up to 60kV.
• $8.76 \times 10^5$ n/s is obtained at 45kV-50mA, $D_2(1.0\text{Pa})$ discharge at Kansai Univ.
• Test of a prototype getter pump was done, and there is no difference in discharge / neutron production characteristics between TMP pumping and getter pumping.
• Relocation of the device to OKTAVIAN, installation of remote operation system have been done.
• Trial of moving into the heavy radiation room and first discharge in the room was successfully made.

We are almost ready to start, remaining issues we need to do are
• trial runs to proof we can do it within machine time (1 week) without any failure, especially tritium handing,
• $T_2/D_2/H_2$ ratio control / measurement in the experiment.