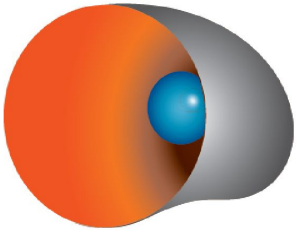


Kyoto Fusioneering

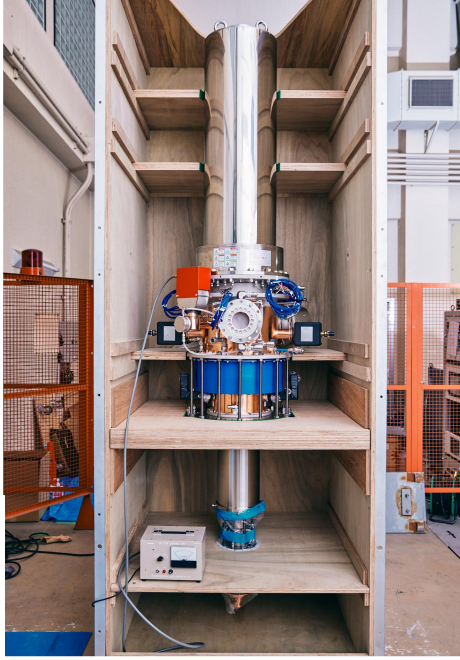
Powering Tomorrow's World

Dr. Richard Pearson, Co-founder & Chief Innovator

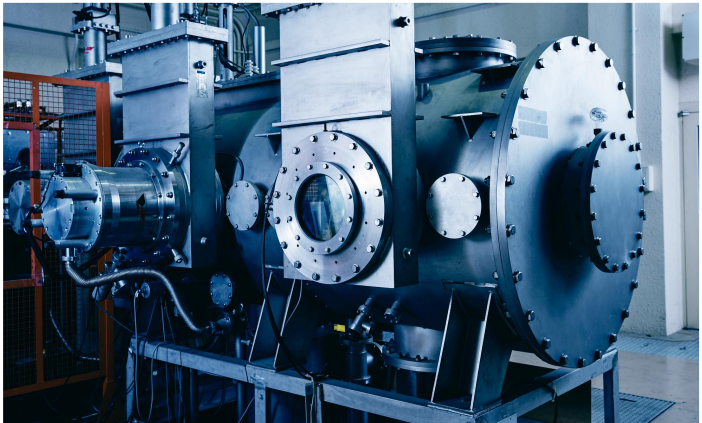
*foreword by **Mr. Taka Nagao**, Co-founder & CEO*

FPA Annual Meeting 2021 | Grand Hyatt, Washington DC, U.S.

Thursday December 16, 2021



Kyoto Fusioneering

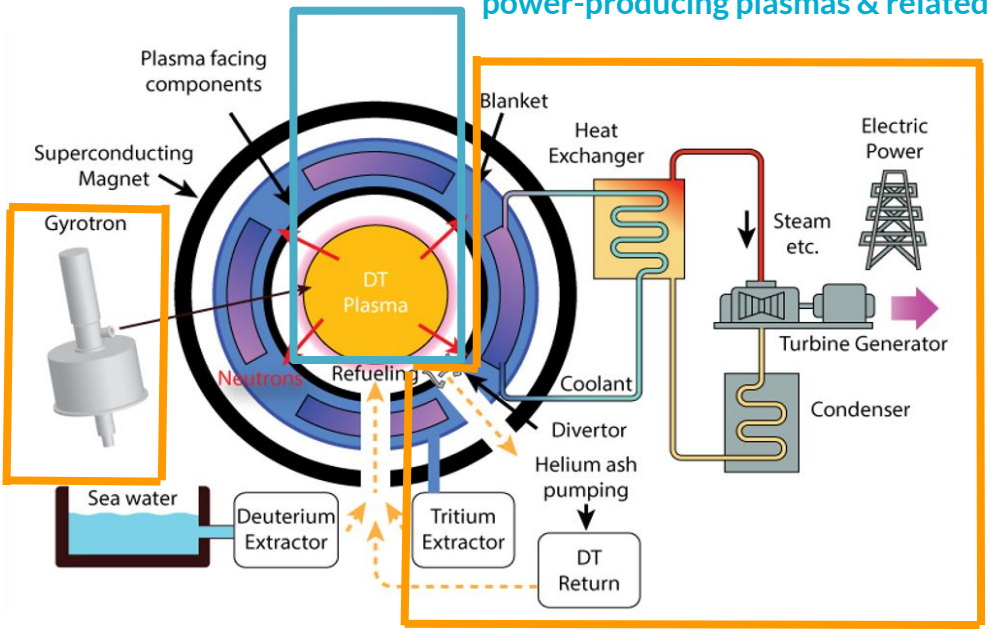


Mission statement

*To accelerate development of **high performance, commercially viable reactor technologies** - associated with **power generation** & the **fuel cycle** - for the rapid expansion of the budding fusion industry*

Kyoto Fusioneering is like Levi's during the Gold Rush: focused on developing critical path technologies required for the industry's success.

Fusion developers globally are working on power-producing plasmas & related tech.



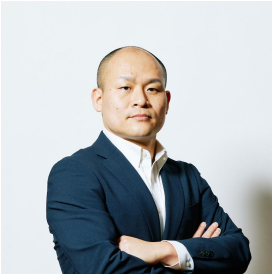
Kyoto Fusioneering is focused on key reactor technologies and engineering.

Company Overview

H2 gas production type fusion reactor

Company name:	Kyoto Fusioneering Ltd.
Established:	October 2019
Funding Amount:	$3.3M (US$) + new VC funds (to be announced Jan 2022) + Japanese government grants
Locations:	Kyoto (Laboratory) Tokyo (Business HQ) London (UK branch)
Number of Staff:	30 (incl. both full-time & part-time) Currently recruiting in both Japan & UK.

Executive Team



Mr. Taka Nagao
Co-founder & CEO

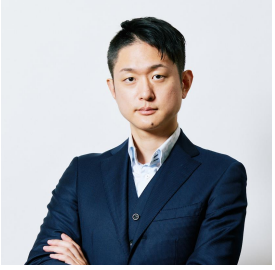
Prof. Satoshi Konishi
Co-founder & Chief Fusioneer

Mr. Takashi Imai
Executive Director
Head of Financial Administration

Dr. Richard Pearson
Co-founder & Chief Innovator

Prof. Keishi Sakamoto
Executive Officer/ Head of Electro Magnetic Division

Mr. Kiyoshi Seko
Executive Officer/ Head of Business and Marketing Division



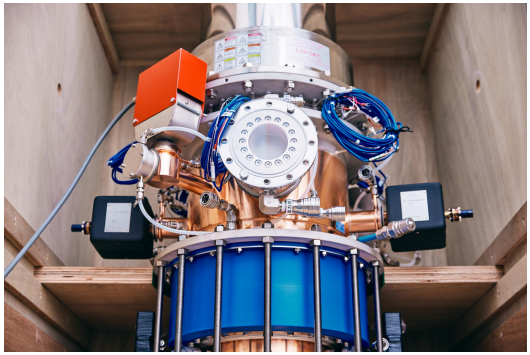
Prof. Shutaro Takeda
Co-founder & Chief Strategist

Achievements

- **Fundraising** secured from top-tier VCs in Japan (amount to be disclosed Jan 2022).
- **Japanese Government grants** - Ministry of Economy, Trade and Industry (METI).
- Contract to supply two **dual-frequency gyrotrons** to UK government facility: **MAST Upgrade** (at UKAEA's Culham Centre for Fusion Energy, near Oxford, UK).
- Awarded **STEP tritium engineering** contract as a Tier 1 supplier by UKAEA, and providing expert support on **blanket** and **commercial pathway** activities for STEP.
- Two contracts with **Japan's national fusion research center** (QST).
- Expanded to **>30 employees**, with a globally diversified team, and have officially set up a **subsidiary company in the UK**.
- Working in **partnership with Japanese industry** and collaborating with several **international engineering and industrial** organizations.

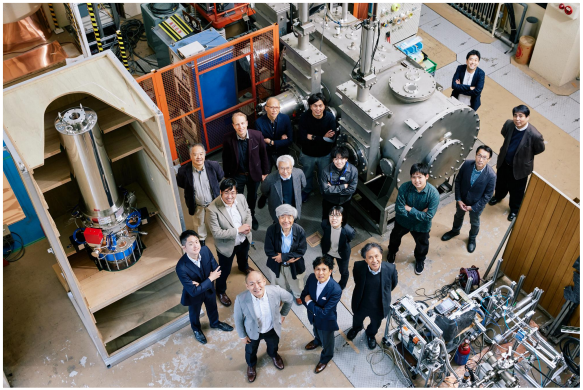
Technologies & Capabilities

1. **Gyrotrons** for plasma heating
2. **Tritium fuel cycle** technologies
3. **Plasma exhaust systems**, incl. H isotope pumping
4. Advanced **tritium breeding blankets** (LiPb, Li and FLiBe)
5. **Liquid metal & salt** technologies
6. **Advanced materials** development, including SiCf/SiC
7. **Fusion neutron experimental** testing and neutronics
8. **Power cycle engineering**, including non-electricity applications (e.g. H2)
9. **Power plant design** and development
10. **Commercialization pathways** support



Advanced gyrotrons (1 of 2)

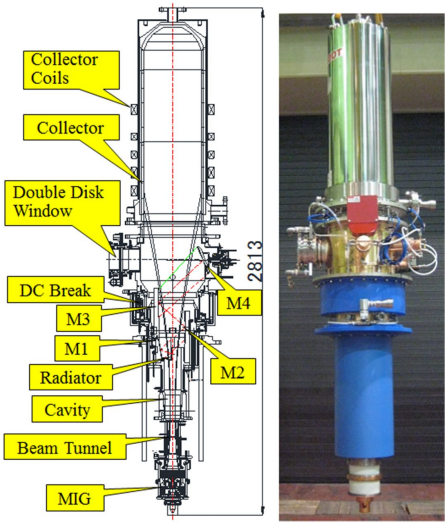
- In 2021, KF has rapidly built its capability in gyrotron engineering, with a **world-leading team** (led by K. Sakamoto).
- Now developing advanced gyrotrons for plasma heating and current drive in **next generation high-field MCF devices**.



- **Collaborating** with major Japanese tech & manufacturing companies: *Toshiba/Canon Electron Tube and Devices (CETD), JASTEC, Kyocera*.
- KF is capable of delivering gyrotrons at any frequency in the mm-wave range; **ready to supply gyrotrons to contribute to global fusion developers.**

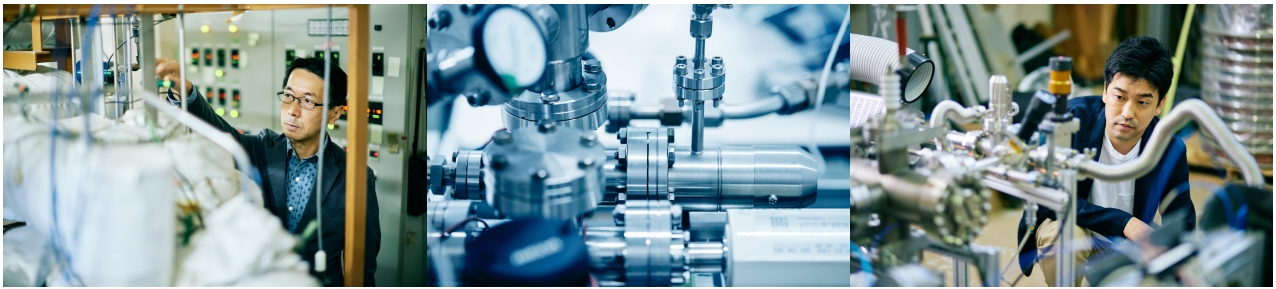
Advanced gyrotrons (2 of 2)

- **Building** & **supplying** gyrotrons **TODAY**:
  - **Dual-frequency gyrotron** (28/35GHz, >900kW) to UKAEA for EBW on MAST-U.
  - Oscillation experiments to be conducted at KF facility in Kyoto & with partners in Japan.
- **R&D to advance technology** towards a step-frequency-tunable gyrotrons **for the FUTURE**:
  - Aim: **236 GHz oscillation** (*although even higher frequency is targeted*)
  - Based on **ITER-type 170 GHz, 1 MW CW gyrotron** tube w/ 9.5T magnetic field & diamond window.
    - *Refrigerant-free 9.5 T magnet under development, with test facility prepared at KU.*
  - **Multi-frequency operation** by optimizing position and pitch factor of the electron beam
  - Potentially **effective for high-field fusion devices** and/or for **higher efficiency current drive system**.



Tritium pump train

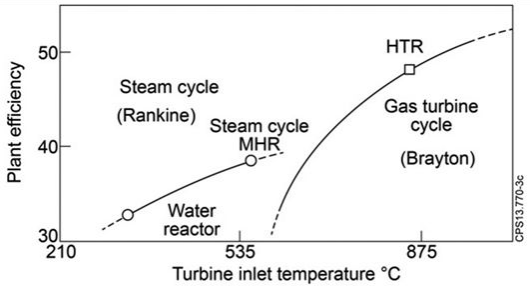
- Fusion reactors require **tritium compatible pumping systems** to sustain a **continuous burning of fusion plasma with fuel recirculation**, *regardless of reactor type.*
- Kyoto Fusioneering Ltd & Kyoto University are developing **three types of pumps** to **evacuate** and **transfer** highly **tritiated gases** for **continuous fuel cycle operation**: as a combined **pump train**.
  - 1) **Proton Conductor Pump:** selective pumping of H isotopes
  - **2) Inorganic Metal Diffusion Pump (Li vapor jet):** replacement for turbomolecular pumps under magnetic fields and/or wet conditions
  - **3) Reciprocating Roughing Pump:** suitable for combination with diffusion pump-proton conductor pump.
- Proof of principle experiments suggest feasibility, but **combination testing** evaluating performance of system needed:- *tests to be conducted by Kyoto Fusioneering in 2022.*

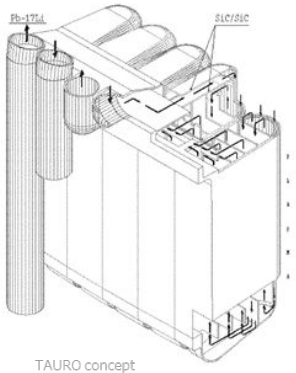


Advanced tritium breeding blankets: SCYLLA© (1 of 3)

- **Breeding blanket** is on the **critical path** for realization of a commercial fusion reactor.
- Strong influence on **performance, cost, lifetime, waste, operational reliability** (etc)
- For fusion to be a **transformative** energy source, **current designs are not advanced enough**: limited performance (low temperature), complex designs, depend on many difficult-to-procure-or-manufacture materials.
- Revivified public & private programmes will see **fusion demonstrators** constructed within the next 5-15 years - some of which will need blanket systems.
- The time for development of an advanced blanket is **NOW** … (*not post-ITER*).
- Kyoto Fusioneering is developing an optimal blanket: **SCYLLA© (Self-Cooled Lithium-Lead "Yuryo" Advanced)**

Federici et al., 2017



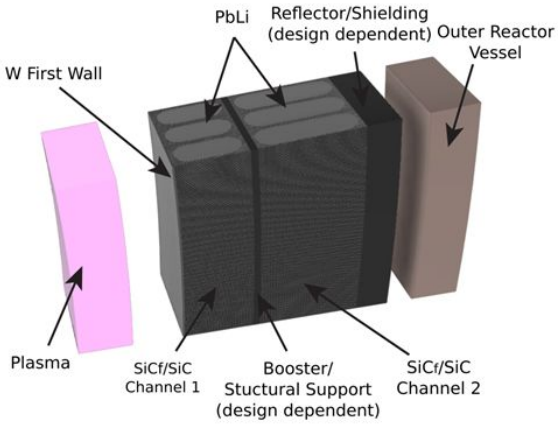


TAURO concept
Giancarli et al., 1998

Advanced tritium breeding blankets: SCYLLA© (2 of 3)

Key features:

- **High-temperature** → high thermodynamic efficiency (Brayton).
- **SiCf/SiC** as a fusion material → strong indication of high temperature and neutron damage tolerance.
- **TBR** → low parasitic neutron absorption loss (high breeder:structure ratio).
- **Li-6 enrichment** → possibility for low (or natural) enrichment.
- **Cost** → raw materials are abundant, cost dominated by manufacturing: new SiCf/SiC method under development in collaboration with Kyoto University.
- **Operability** → avoids MHD effects due to non-metallic structure, fully drainable (molten metal LiPb), low-density structure (SiCf/SiC 3x lighter than steel), online servicing (purification, T extraction).
- **Safety** → intrinsic due to no pressurised media, production of unwanted isotopes a known issue to be solved.
- **Waste** → Simple design facilitates EOL handling, SiCf/SiC relatively low radiotoxicity at EOL, C-14 production is a known issue to be solved.



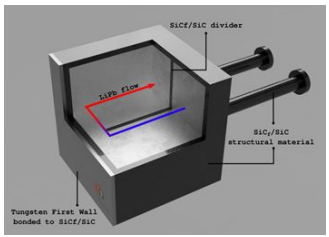
Kyoto Fusioneering's **SCYLLA©** (**S**elf-**C**ooled **Y**uryo* **L**ithium-**L**ead **A**dvanced blanket)

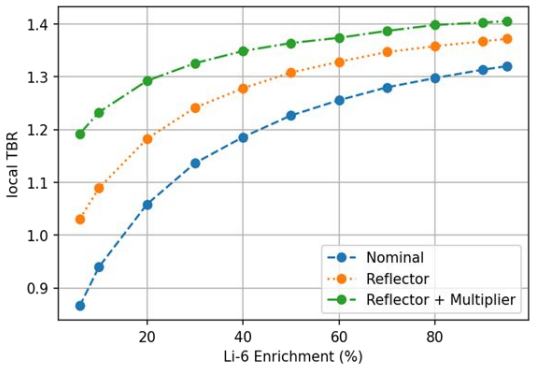
**Yuryo = "superior" in Japanese*

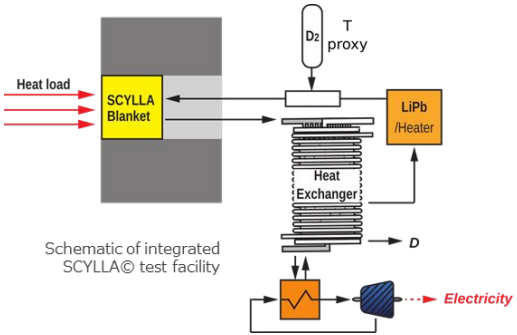
Advanced tritium breeding blankets: SCYLLA© (3 of 3)

SCYLLA© activities at Kyoto Fusioneering:

- **Design studies** → including neutronics and TBR assessment.
- **Commercial studies** → including supply chain, integration with power cycle (etc).
- **Manufacturing** of **novel fusion-grade SiCf/SiC composite** → collaboration w/ Kyoto University.
- **Experimental R&D on LiPb** → including materials compatibility, T extraction, heat transfer etc.
- Developing **integrated SCYLLA test loop** → integrated R&D and simulated blanket testing.



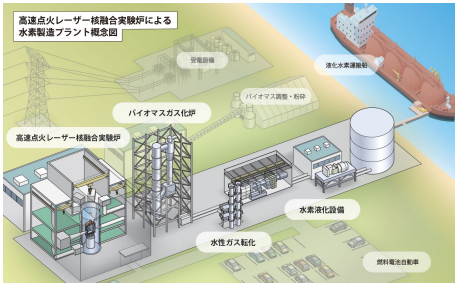




Challenges remain, but no showstoppers: SCYLLA© can be an advanced blanket option ready for design into fusion energy demonstrators pre-2030.

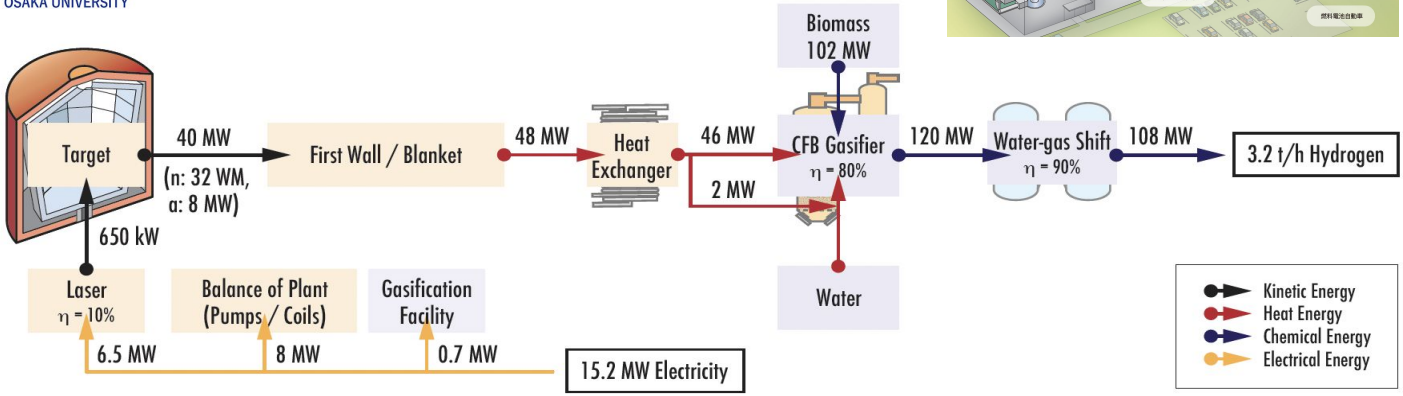
Power plant and H2/Carbon capture

- **Power cycle engineering**
  - High-efficiency Brayton cycle engineering
  - H2 generation technology
  - Biomass gasification and carbonization
  - Technoeconomic modelling
- **Commercialisation support**
  - Strategic planning (roadmapping)
  - Power plant design
  - Assessment of non-technical challenges



OSAKA UNIVERSITY

KF collaboration with Osaka University HYPERION (Hydrogen Production with Energy Reactor of Inertial Fusion) concept
(Hydrogen production from an IFE reactor)



Summary

- Kyoto Fusioneering is **rapidly expanding:** backed by **top-tier VCs**, **30+ people** (and growing!) & launch of **UK subisidary**.
- Developing **key technologies which are on critical path of fusion commercialization** - *both near-term and longer-term* - providing engineering solutions and technology to developers globally.
- Collaborating with **Japanese Universities and National Laboratories** such as Kyoto University (exclusive partnership), Osaka University, Tsukuba University.
- Coordinating the **Japanese fusion supply chain**, bridging the expanding global fusion industry and Japanese high-tech and manufacturing capability.
- Working to **accelerate development & industrialisation of fusion**, to create a **new energy society**.

Kyoto Fusioneering

ありがとうございます!

(Thank You!)

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