Feasibility Study of Fuel Debris Cutting and Dust Collection Technology for Innovative Approach

<ONET TECHNOLOGIES NUCLEAR DECOMMISSIONING>

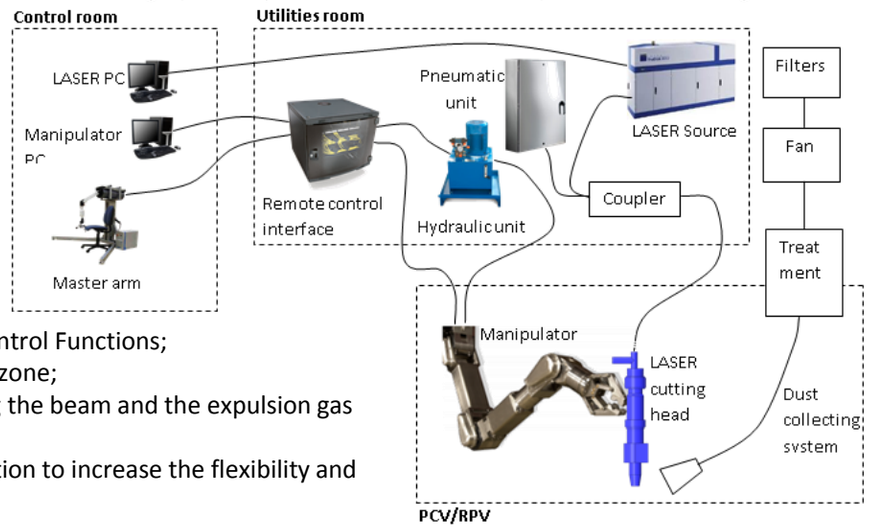
Purpose and Goal

High power lasers technology could present a great interest for fuel cutting in PCV and RPV. It has very **good cutting performance**, it leads to **less secondary outlets** than most of other thermal cutting techniques, it allows **limited production of scrubs,** it is **easily automatized** and used for activities under high dose rate with a **remote controlled** manipulator. At present, laser cutting is used in various nuclear facilities and is starting to be used in **nuclear reactors decommissioning**, especially when remote operation is mandatory. The purpose of this feasibility study is to **assess the applicability** of the developed process and relevant technology to fuel debris retrieval.

Overview and Feature

The proposed high power laser technology has a wave length of ~1µm, which can be obtained from different sources (Nd YAG, Fiber, disk). Apart from the different wave length, the implementation is the same, with the following features:

- A multi-kilowatt power CW laser source whose laser beam can be carried by optical fiber;
- A laser beam conveyance device made of one or more optical fibers connected by optical couplers;
- A carrier/manipulator for the displacement of the laser torch;
- A set of utilities for device control Functions;
- Separated hot zone and cold zone;
- A laser cutting torch ensuring the beam and the expulsion gas jet shaping;
- Torch special optic configuration to increase the flexibility and
- cutting performances



Two CEA patented designs of torch are foreseen for this application:

- Air torch, with gas cooling and expulsion gas, exclusively for in-air cutting
- Water torch, with water cooling and beam protection, and expulsion gas that can be used for in-air and underwater cutting

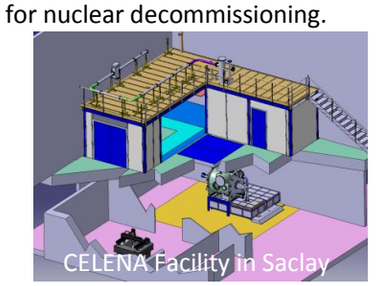
The project is focusing on the demonstration by trials of the applicability of laser cutting to fuel debris simulants, using the CEA following strong points:

- **VULCANO Facility** existing fuel debris samples, that are used as simulants for the trials
- **CELENA laser cutting facility**, where the cutting tests are implemented

The project is also focusing on the **remote adaptation of the laser cutting** and the cutting strategy into the RPV / PCV, using **ONET strong experience** on remote handling and use of laser for nuclear decommissioning.


Laser cutting of a dissolver


Laser cutting remote implementation


CELENA Facility in Saclay

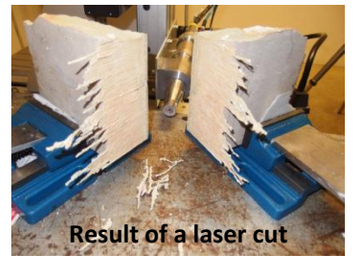
Outcome obtained

Outputs from the laser tests:

One of the main focus of the study was the implementation on laser cutting trials on fuel debris simulants to assess the behavior of this material :

- We have defined and chosen 3 simulants from available samples to be representative of in-vessel and ex-vessel fuel debris;
- A first series of trials have been run and have demonstrated good performance of laser cutting on the provided simulants: (cutting up to 100mm thick plates of simulant with an 8kW laser);
- The second series of trials have been run and to assess the impact of sand off, gas pressure, angle effect and starting conditions, and have demonstrated the capability to remove a small piece of material from a massive fuel debris.

These outputs produced knowledge of the behavior of fuel debris like material with an associated range of cutting parameters and led to the proposal of a specific design, to improve the cutting performances especially for non-emerging cuts.


Result of a laser cut

Outputs of the dust and collection system

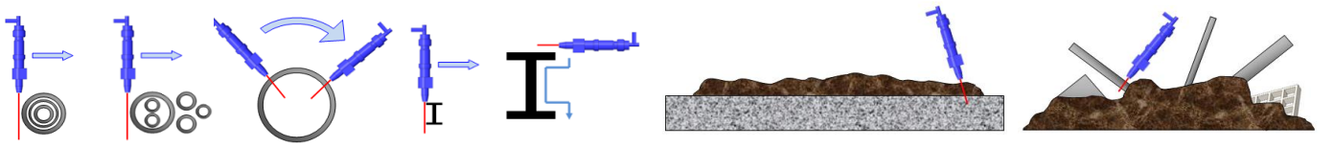
Studies have been done to estimate the dusts and fumes production during the laser cutting. The outcomes of these studies gave a estimation of the mass, the size distribution and the quantity of aerosols produced during a laser cut. This estimation have been used to propose dust and fume collection systems, from collection at the source to a global ventilation system. Efficiency of each system, and associated preliminary concepts have been made to confirm the feasibility of dust and fumes collection and treatment.

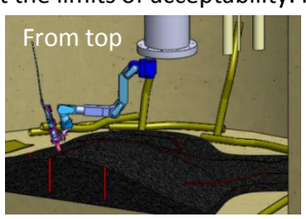
Outputs related to radiation resistance

Studies have been done on the radiation resistance of the laser specific components as the optic fiber. These studies showed that the main effect is a reduced irradiation attenuation with a consequence of increasing the losses in the fibers. The studies have shown that 2MGy cumulative dose and 10 kGy/h dose rate are bringing the fibers to losses at the limits of acceptability. However, it seems achievable to adapt / improve the fibers to confirm this feasibility. Radiation resistance of the other materials have also been assessed, with a focus on the manipulator.

Outcomes related to on-site implementation

We have defined all the functions and constraints for the deployment in the Fukushima Daiichi damaged reactors.
These studies led to the proposal of two scenario of fuel debris cutting, accessing from the top of the RPV or from the side of the PCV. These scenarios have detailed the main cutting operation to be implemented (including on the reactor internal structures) in association with the laser cutting capabilities.
The on-site implementation studies also covered the potential layout of the equipment to be installed in the reactor building, the maintenance need and the deployment principle.




From top


From side

Challenges and Issues in the future

The two main challenges for the on-site application are:

- The radiation resistance of the manipulator and the optic fiber, which will be a real thread for the technology in air.
- The improvement of the cutting performances for non-emerging cuts, through the development of a specific design of the laser torch.

Other challenges can be mentioned as:

- Aerosols production and confirmation of collection need;
- Knowledge of the RPV and PCV congested environment;
- Manufacture and/or sampling of activated fuel debris to support the trials prior on-site implementation