# Electrostatic Levitation Furnace for the ISS

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**Abstract**

JAXA (Japan Aerospace Exploration Agency) has just started the development of Electrostatic Levitation Furnace to be launched in 2014 for the ISS.

This furnace can control the sample position with electrostatic force and heat it above 2000 degree Celsius using semiconductor laser from four different directions. The announcement of Opportunity will be issued soon for this furnace.

In this paper, we will show the specifications of this furnace and also the development schedule.

**Introduction**

As for microgravity material science research, JAXA has started the development of Gradient Heating Furnace in 1993. The GHF has been launched by H-II Transfer Vehicle #2 last year(2011). At that time, Electrostatic levitation Furnace (ELF) was also the candidate of the JAXA multi-user facility for the ISS. Because of the technical difficulty of ELF, the start of the development of ELF has delayed, and also the ISS assembly schedule has delayed. Since then, many circumstance conditions has changed (such as rack location availability, crew time availability, maximum development cost and etc.), so the specification and requirements have also changed. Through these hard time, JAXA started the development of ELF in February 2011. The ELF will be integrated into Multi-purpose Small Payload Rack (MSPR) in KIBO. The launch target year is 2014.

**History**

In 1993, at Furnace Workshop which was held at ESTEC among the each space agency (CSA, ESA, NASA and JAXA), JAXA presented the intent of developing ELF and also preliminary specifications was presented. At that time, DLR has presented Electro-magnetic Levitator Furnace, based on the result of Shuttle equipment TEMPUS. In 2000, Levitation Furnace Workshop was held at San Diego, USA. There NASA, ESA and JAXA has discussed and came to some conclusion, that each agency's furnace contribution. The image of the contribution is shown in Table 1.

**Specification**

ELF has been developed based on a design by Rhim et al.[1)] from which several modifications were made. Fig. 1 depicts schematically the ELF and its optical diagnostic instruments. The electrostatic levitation method utilizes the Coulomb force between the sample and the surrounding electrodes. A positively charged sample was levitated between a pair of electrodes which were utilized to control the positions of the specimen.

Table 2 is the latest specification of the ELF. The heating lasers hit the sample from the top of regular tetrahedron to center, so that the sample temperature could be isothermal.

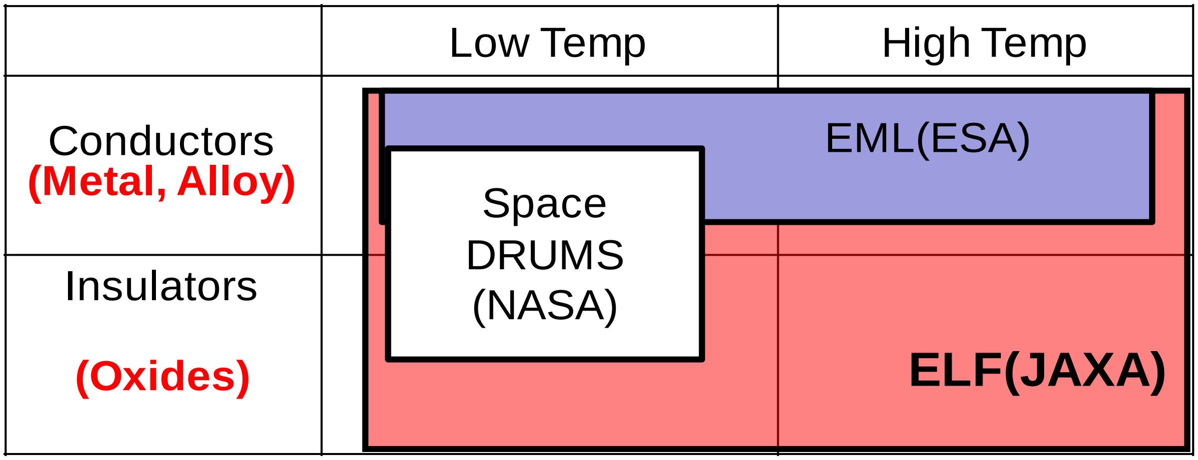


Table 1 Levitation Furnace Contribution of each space agencies

To integrate the ELF into MSPR, vacuum pump was deleted, so the samples which requires high vacuum condition are impossible with ELF. The maximum environment pressure is 0.2 Mpa. And the best vacuum condition is worse than 0.13 Pa. ELF can control the environment pressure between those values with $N_2$ or Ar. We plan to conduct the oxides sample in the maximum pressure so that the outgas from the sample become minimum. When we process metal samples with ELF, we will choose Ar environment in which we can not levitate samples in 1-G condition. The cleanliness of the supply gas are shown in also table 2.
Figure 2 shows the rough images of ELF sample chamber. ELF experiment chamber is polyhedron shape so that the chamber accommodates many optical windows in minimum chamber size and enables us to set various functions(such as heating, sample position detection, observations and etc.) .

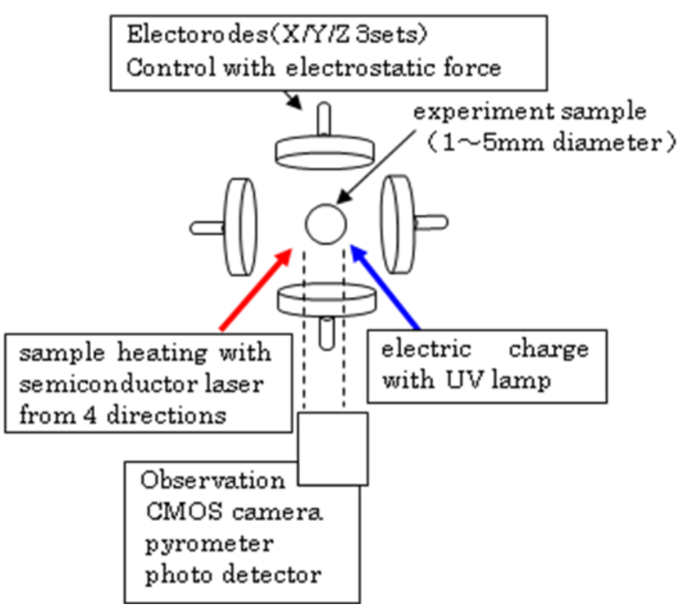


Figure 1 Schematic drawing of the ELF

ELF is equipped an UV lamp (peak wavelength;365nm) to assist the electric charge of the sample so that ELF electrostatic positioning control can maintain the sample position to correspond to the sample charge decrease, caused by such as outgas from the sample.
ELF usually control the sample positions at 1 kHz frequency. This position control frequency can be reduced by ground commanding as well as PID control parameters.

**Utilization Concept of ELF**

To demonstrate the ELF capability, we are now planning to process the oxide samples, whose melting temperature are over 2000 degree Celsius. The thermophysical properties such as density,

surface tension, and viscosity will be measured over wide temperature range including under cooled region. The density can be calculated using magnified image of the molten sample[2], while surface tension and viscosity can be measured by oscillating drop method[3]. We will superimpose the oscillation signals to position control voltage. Then measure the sample oscillation with photo detectors with vertical slit. 5 kHz of oscillating data would be down linked to ground for the measurement. The processed samples will be retrieved to the ground. These process would be conducted as ELF initial check. Some thermophysical properties of molten oxides have not been measured on the ground and will be the first measurement in the world. Also we plan to investigate the detailed structure of the processed sample on ground.
By using ELF, we can obtain the cooling curve of the sample, with which we may calculate the heat capacity of the sample if we can estimate the conductive heat transfer by surrounding gas.
The processing sample would be installed into cartridge (up to 15 samples per cartridge), and then launched by HTV(H-II Transfer Vehicle) or other launch system. After installing the cartridge into ELF chamber, each sample can be processed by ground commanding. The images of the sample and equipment telemetry data would be down linked to ground automatically, when we oscillate the sample, we plan to get the resonance frequency and attenuation factor of the sample. After the experiment, the sample cartridge would be retrieved by Space-X or Soyuz to ground.
The ELF chamber equipped double seal and around the chamber connectors, there is decompression environment, so that ELF can provide three protecting method for the sample vapor gas. After each measurement, the inner gas could be replaced by ground commanding.

Table 2 Specification of ELF

| Items | | Requirements |
|---|---|---|
| Sample Size (diameter) | | 1 ～5mm |
| Accuracy of Positioning | | ±100micro meter |
| Heater | Laser (Wave Length/Power) | 980nm(TBD) ／40W x 4 directions |
| | Target Temperature | Melting Point of Zirconia (2710 degC) |
| Observation | Temperature Measurements | one thermometer (ORU)(range;1450-1800 nm(TBD)) Sampling Rate (more than 100Hz) equipped with one camera(NTSC) |
| | Magnified Image | One camera with zoom (NTSC) higher than 140 pixels/ half diameter (1mm) |
| | Observation of Overview | One camera with zoom (NTSC) |
| Measurements of Thermo-physical Properties | Density | through Image Analysis |
| | Surface Tension | Oscillating Droplet Method |
| | Viscosity | Oscillating Droplet Method |
| Others | Ambient | $N_2$ Gas(Level300A)* Ar Gas(Level300A)*, Vacuum with Evacuation Line |

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## Development Schedule

Figure 2 shows the development schedule of ELF. Launch target year of ELF is 2014. Using the engineering model, we plan to verify the sample control logic with parabolic flight. After that verification, the engineering model would be modified to training/ground model.

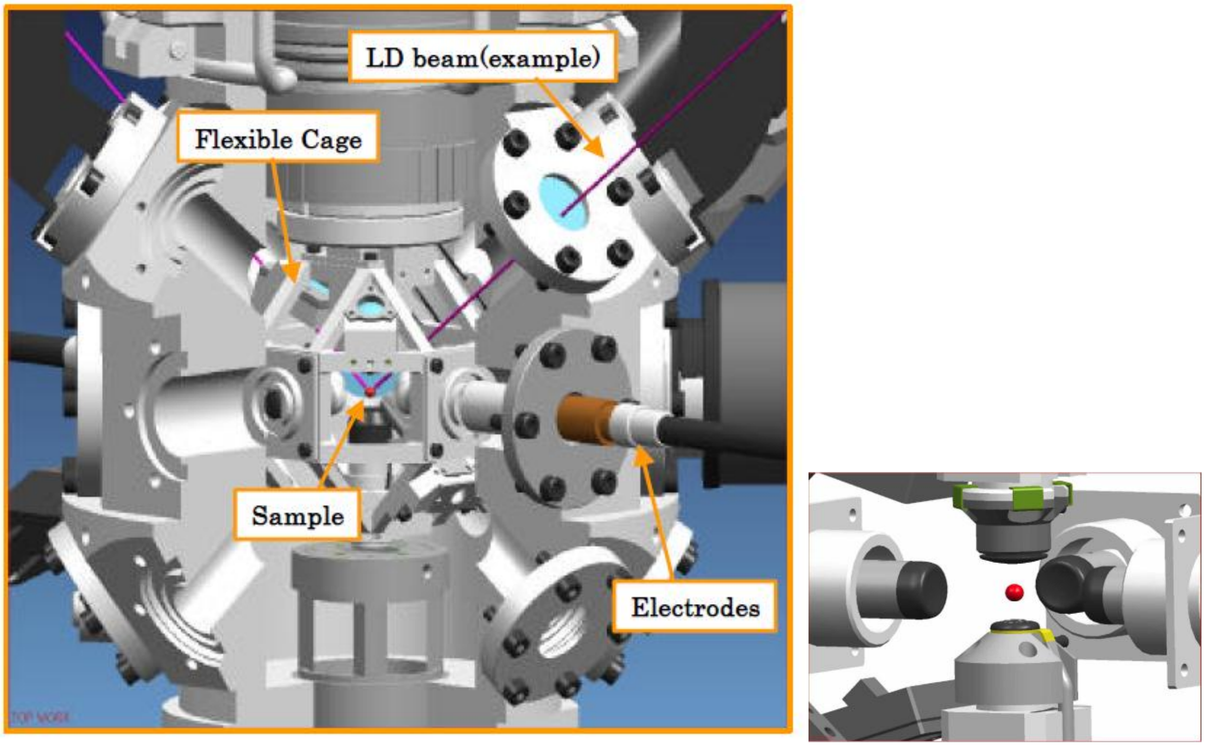


Figure 2 Sample chamber images of ELF

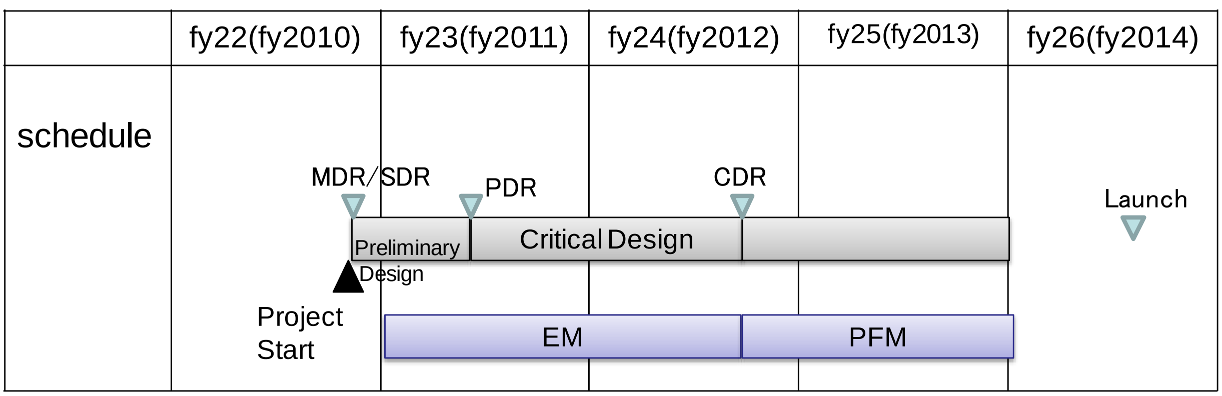


Figure 3 Development Schedule of ELF

**Conclusion**

Announcement of Opportunity (AO) will be issued for the ISS experiment (including the usage of ELF) at Japan in February 2012. We hope many researchers are interested in ELF and apply to the AO.

**References**

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