SYSTEM ENGINEERING TO MEET CONTRADICTING REQUIREMENTS

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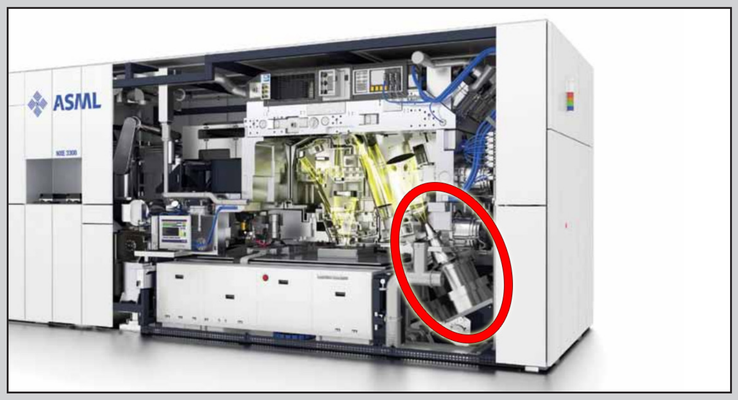
INTRODUCTION

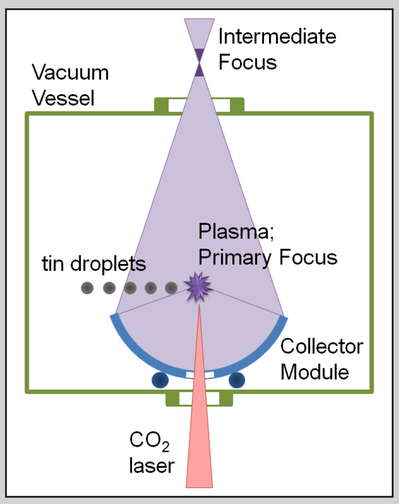
High accuracy, high thermal loads and high vacuum environment seem to be conflicting requirements for the design of a system. By separating functions we found solutions to meet these requirements. VDL ETG and Settels Savenije van Amelsvoort designed and built a vacuum system (D x h = 1.5m x 1m) for a light source for EUV lithography, where mechanical tolerances are within 100 µm absolute and less than 10 µm on local level.

APPLICATION



EUV Lithography tool *[images, ASML's customers magazine; 2012 issue 1]*

FUNCTIONS



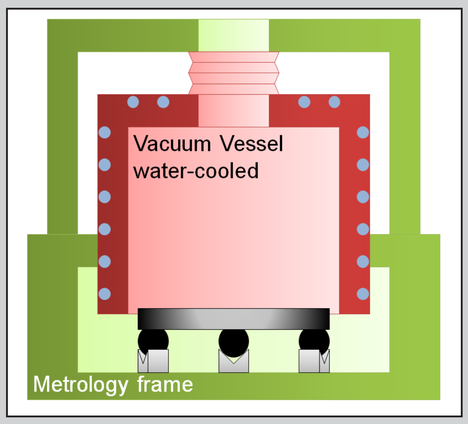
A CO_2 laser beam hits tin droplets in the Primary Focus of the collector module and an EUV light emitting plasma is produced. The emitted EUV light is focused in the Intermediate Focus point by a Collector Module and delivered to the scanner. The functions of the EUV source that can be distinguished are:

- Create a plasma
- Focus emitted EUV light in Intermediate Focus
- Create an optical axis; accurate mechanical interface to Intermediate Focus
- Create vacuum environment
- Temperature control; absorb heat from plasma

SYSTEM DESIGN

The power of the CO_2 laser is in the order of tens of kilowatts and the power of the produced EUV beam is less than 500W. Almost all the power of the CO_2 laser should be transferred through the vessel wall and absorbed by the cooling water. The thermal expansion of the vacuum frame as result of the heat load from the plasma and deformations caused by vacuum loads are too big to meet the accuracy requirements.

We need to separate functions. A stiff metrology frame is used to create an optical axis and inside this metrology frame the water-cooled vacuum vessel is mounted to create a vacuum environment. Heat load and vacuum forces are absorbed by the vacuum vessel; accuracy is determined by the metrology frames.



COLLECTOR INTERFACE

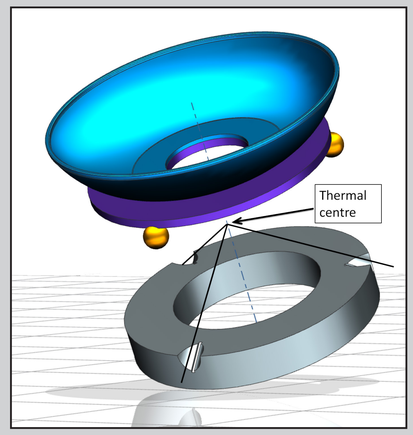
Part of the tolerance stack is the Collector Module interface. The Collector Module is mounted in the metrology frame. The requirements on absolute accuracy are high, but also the requirement on repeatability is strict when replacing the component. A stiff kinematic mount is designed: 3 balls in 3 V-grooves, with the thermal centre in the focus of the Collector Module.

Contact Stiffness

Si_3N_4 balls on hardened tool steel V-grooves (AISI 420) give a Hertzian contact stiffness of $3 \cdot 10^8$ N/m. The orientation of the V-grooves is so that the surfaces of the V-groove form 3 perpendicular surfaces. Now the translational Hertzian stiffness is approximately equal in 3 degrees of freedom: two times the contact stiffness in a contact point: $6 \cdot 10^8$ N/m.

Coefficient of Friction

Self-alignment is the situation that the Collector Module is aligned by gravity forces. The allowed coefficient of friction for self-alignment is evaluated for the V-groove configuration and is about 0.4 [-]. Measurements are done on the coefficient of friction of Si_3N_4 balls on Diamond Like Carbon (DLC) coated hardened tool steel and the measured coefficient of friction is 0.03-0.045 [-] which is a factor of 10 lower than the allowed coefficient of friction for self-alignment.



Repeatability Measurements

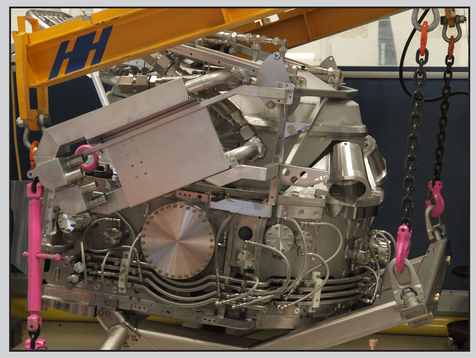
Repeatability measurements of the V-grooves interface are done. A dummy Collector Module with three reference balls is placed on the V-grooves and the locations of the reference balls are measured on a coordinate measurement machine in x, y and z. The repeatability of the collector mount is better than 10 micrometer.

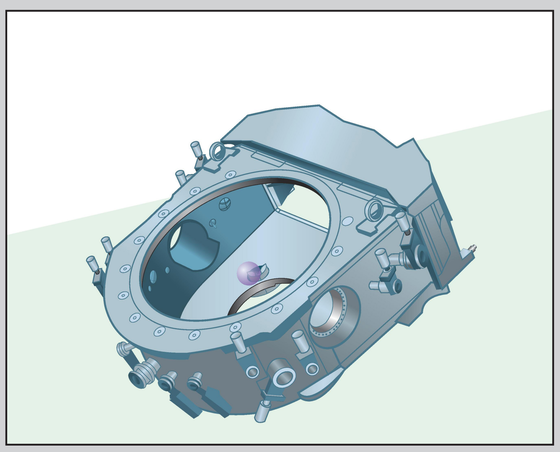
OPTICAL AXIS MEASUREMENT

After assembly the error of the interface to Intermediate Focus is measured. Therefore the Collector Module interface and the interface to Intermediate Focus are measured with a coordinate measurement machine. A perfect Collector Module is assumed to transfer the measured values of the Collector Module interface to the Intermediate Focus interface. The error of the interface to Intermediate Focus with respect to the optical axis of the EUV beam is less than 100 micrometer radial.

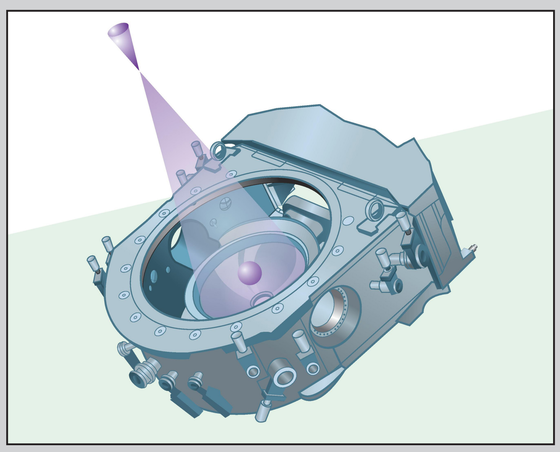
CONCLUSIONS

By separating functions it is possible to meet specifications that seem to be conflicting. With a vacuum frame that absorbs the heat load and creates a vacuum environment and an accurate metrology frame to create accurate mechanical interfaces all specifications are met. A design is made for an accurate and stiff repeatable interface for the Collector Module.

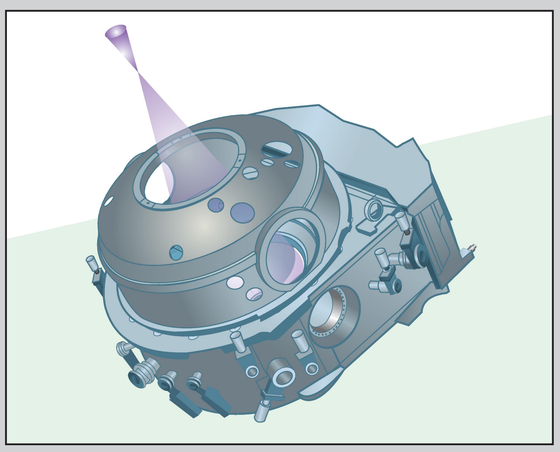




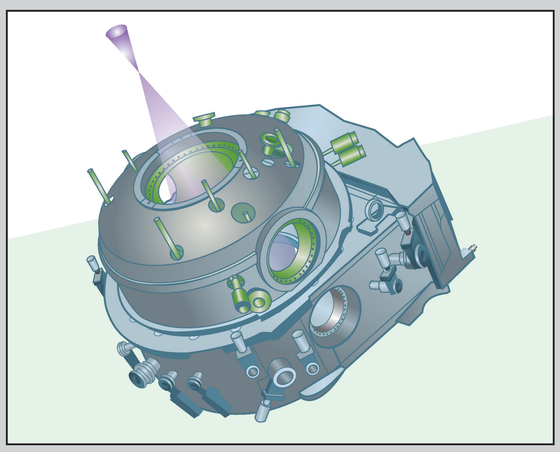
create a plasma



focus emitted EUV light in Intermediate Focus



create accurate mechanical interfaces to Intermediate Focus



create vacuum environment and absorb heat load

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