Thermal Considerations

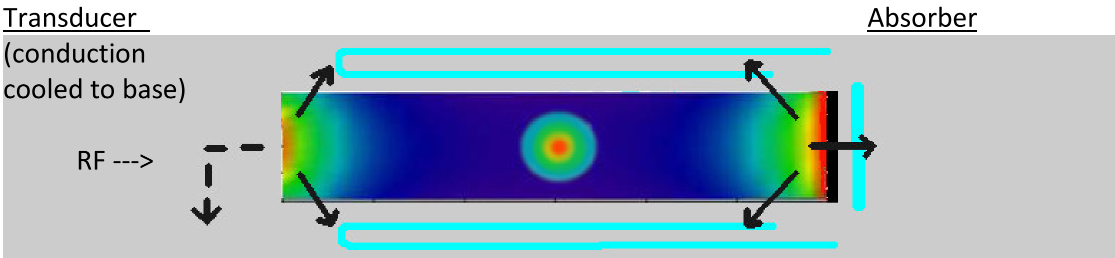


Figure 1

Figure 1 is a visual representation only, showing typical hot spots in a high power water cooled AO crystal. Acoustic wave is generated by the RF at the transducer and this wave travels through the crystal to the absorber. The absorber is designed for low acoustic reflection.

The laser beam is shown by the concentric circles.

Optical absorption in the bulk crystal {e.g. Germanium) and A/R coating will cause thermal effects due to laser power alone, with or without RF power. The thermal gradient across the beam will depend on the beam profile.

With RF power applied, there is additional thermal load from conversion losses at the transducer and heat generated at the crystal absorber.
The transducer is cooled by conduction through the electrode contact pressure block into the base and through the Germanium to the upper and lower water cooled surfaces. (As arrowed)

The absorber has a water cooled channel running immediately in contact with the absorber material. There is also conduction through the Germanium to the upper and lower water cooled surfaces. (as arrowed).

The upper and lower surfaces of the Germanium block are cooled in one of two ways, depending on the model (see Figure 2).

1: Direct contact: Coolant washes the Germanium block directly. The block is fitted in the case with "O" rings. e.g. AOM640, AOM740, DBM1186, M1192, M1208, 1209, LS600, LS700 series

Advantages:	Highest cooling capacity. Best method for CW RF operation.
Disadvantages:	Coolant pressure restricted to 3 bar / 50 psi. Corrosion may cause leaks around the "O" rings, especially when a corrosion inhibitor is not added.

2: In-direct contact: Coolant flows in the case parts but is not in direct contact with the Germanium block. No "O" rings needed. ("Dry" design). e.g. D1135, M1312, D1340, M1315, M1189, M1199 series.

Advantages:	Allow high coolant pressures, very low risk of coolant leak.
Disadvantages:	Moderate cooling capacity. Suited to duty cycled operation or applications with lower average RF drive powers.

The in-direct method can be used for CW high RF power applications (e.g. 10.6um devices) but thermal lensing and beam drift are likely to be higher.

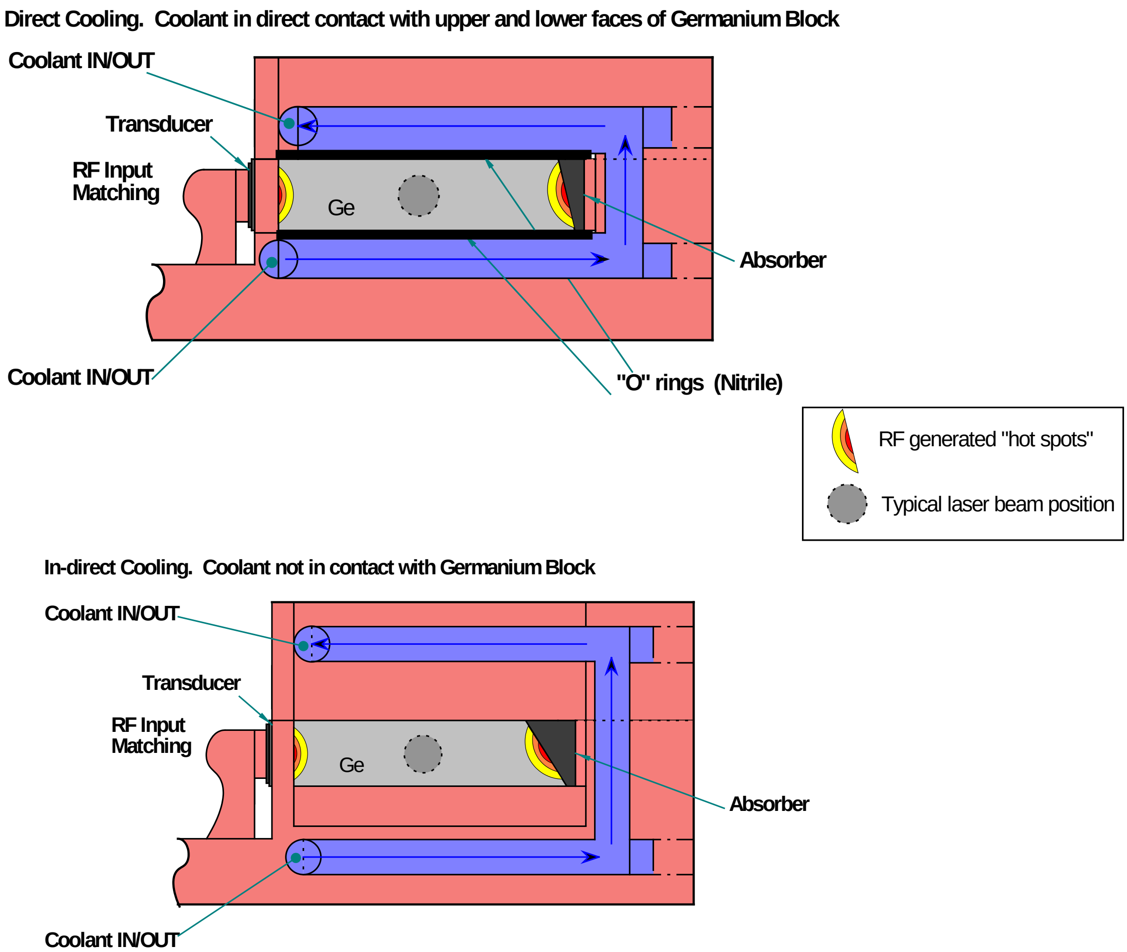


Figure 2

Thermal Lensing

All Germanium AO devices suffer some distortion due to thermal effects.

There are two main factors:

- The heat generated due to the high RF driver power.
- Localised thermal gradients due to bulk optical absorption.

The first is the major cause of thermal lensing and has a cylindrical focussing effect. The AO devices are designed to minimize thermal gradients across the Germanium block but at the same time must ensure adequate cooling. The coolant temperature is important and as a general principle, the colder the better (recommend < 20degC).

The second is minimized by specifying high grade optical Germanium, with a typical bulk absorption of < 2% per cm.

Consider a 250W input beam. The power dissipated due to optical absorption will be < 20W. This compares to ~100W of RF drive, most of which is dissipated as heat at the absorber.

Thermal Stabilization

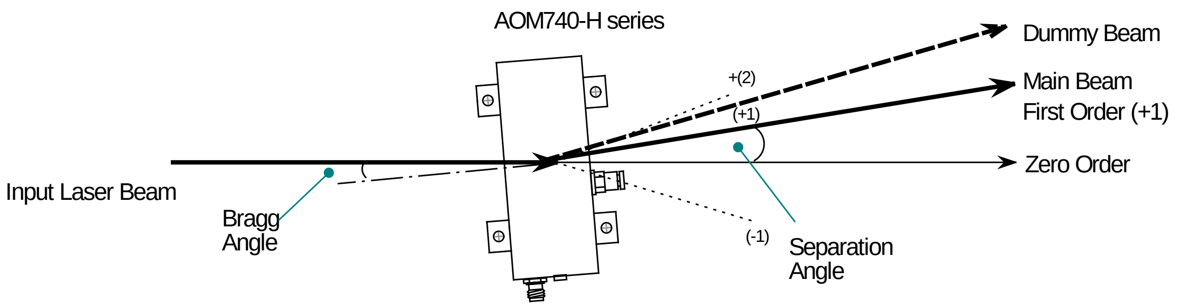
Under appropriate conditions, the thermal lensing can be compensated with a lens of opposite power. To be effective, the AOM induced lensing should have a near constant focal length.

- Optically induced thermal lensing is constant, provided the laser is on continuously.

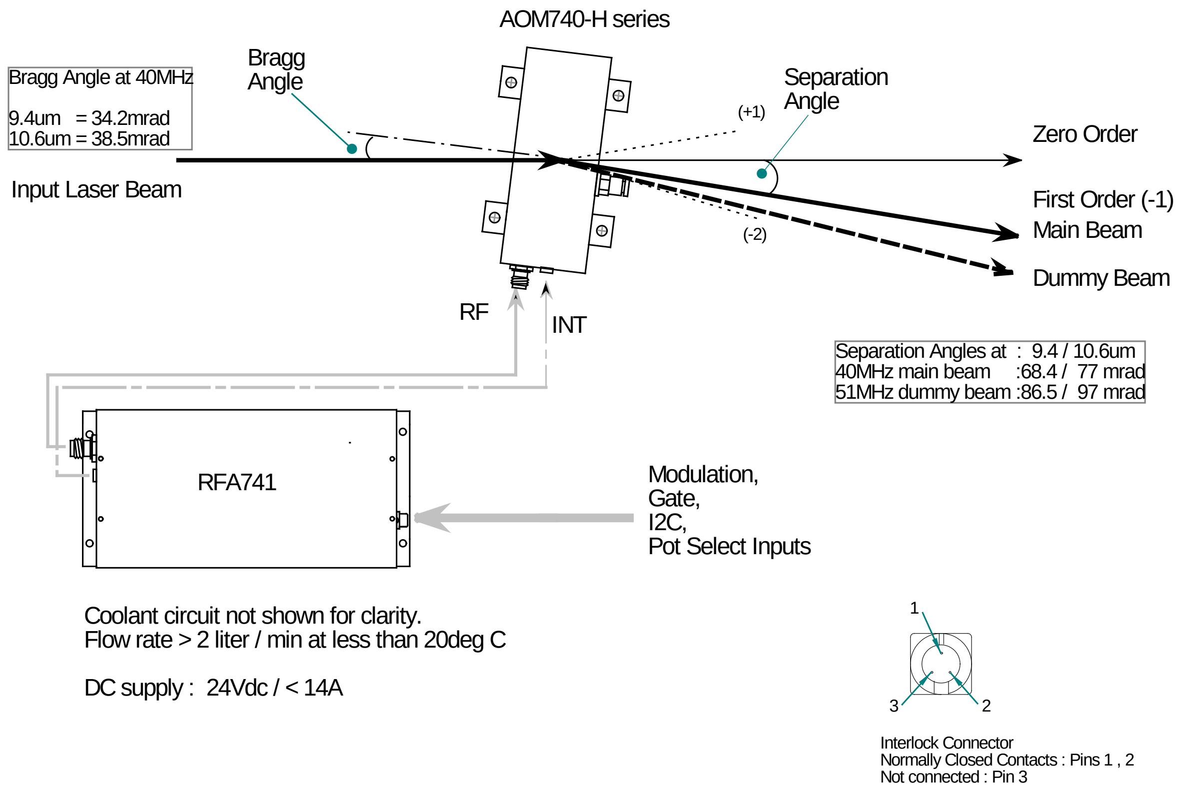
- RF induced thermal lensing depends on the applied duty cycle of the modulation signal.

For most CW laser applications, this can vary from 0 to 100%. One compensation technique involves inducing a near constant thermal load by switching between two RF drive frequencies.

This method is well suited to digital modulation and is illustrated below. The main “working” ON beam is adjusted for high diffraction efficiency. The secondary “dummy” beam results from the OFF drive frequency. This dummy frequency needs to be with the pass band on the transducer and will thus will diffract optical power. The efficiency of this diffraction is immaterial. We are only concerned with matching the thermal dissipation in the “OFF” condition



(or)



This technique requires an RF driver with suitable frequency switching control, an AO transducer bandwidth sufficient for 2 sufficiently separated frequencies and in the system, a beam block for both zero and dummy beams.

e.g. Isomet AOM740-8 and RFA741 driver

ON frequency: 40.0MHz
OFF frequency: 50.7MHz

Condensation

Germanium AOM's operate at lower loss, and with lower thermal lensing effects
when the coolant temperature is below 18-20degC

This can be a problem where the humidity is high.

Condensation on the Optical surfaces will after some time (typically many days - weeks) degrade the A/R surface and reduce the life time of the AOM.
If this condensation 'creeps' onto the transducer bond, the device may fail prematurely.

One solution is to add a dry nitrogen / dry filtered air feed to the AOM
A small positive pressure will keep dust and humid air away from the optical surfaces

Modulation Time

The optical switching time is defined by the transit time of the acoustic wave across the beam waist in the AO crystal.

For a Gaussian beam the optical rise time can be approximated by the formula

$$\mathbf{Tr = 0.65 \times \frac{Beam\ diameter}{Acoustic\ velocity}}$$

Acoustic velocity for Geranium is 5.5mm/usec

Thus for 6mm beam, the optical rise / fall time is ~700nsec

Modulation bandwidth is approximated by: BW_mod = 0.35/Tr
For 6mm beam, bandwidth is 500KHz

The RF driver power is proportional to the active aperture height of the AO device.
Ideally the active aperture heights should be 1.5x the 1/e^2 diameter of the laser beam at the AOM.
There will be design comprises to this ideal in order to limit the RF drive power and resulting thermal issues.