

Procedure to Estimate Transmit Beam Divergence from Satellite Scanning

Context

It is increasingly necessary for SLR stations to know their laser beam energy densities at satellite heights. Using this information, satellite mission operators can assess the potential hazard posed by SLR to sensitive on-board equipment. This note describes a method to estimate laser beam divergence from satellite scans. Further details on this technique can be found in *Burris et al*, 2013.

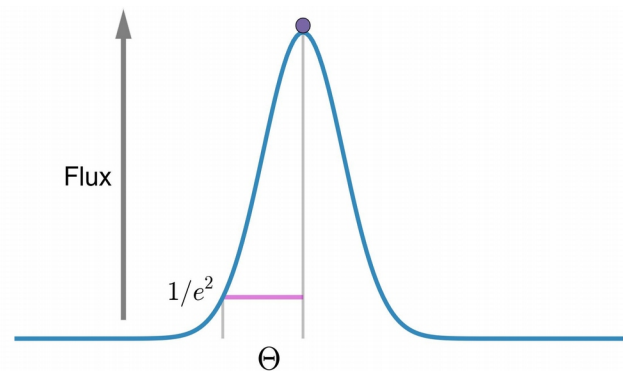
What is needed for the beam divergence estimation?

The goal is to determine the $1/e^2$ beam divergence half angle. This is calculated from 2 terms which are measured by extinguishing the satellite return signal, first by changing the telescope pointing and then by reducing the system energy.

The divergence, θ_t , at which the intensity falls to $1/e^2$ of the beam centre is determined by:

$$\theta_t = [-2\theta_s^2/\ln(F)]^{1/2}$$

where: θ_s is the scan half-angle (microradians or arc-seconds) to extinguish the signal.
F is the system energy reduction factor required to extinguish the signal.

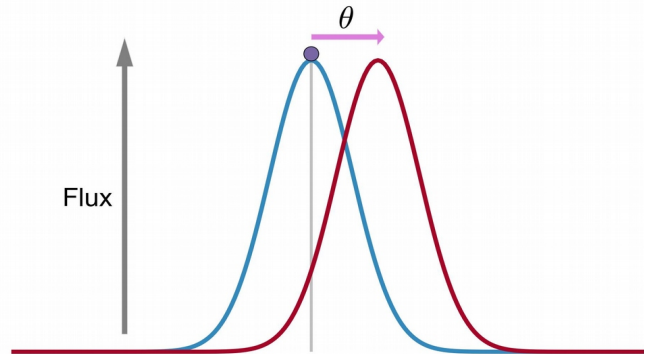


Procedure

Measurements are best performed at night in a cloudless part of the sky. For a strong signal, remove any daytime filters, open the iris and choose a satellite with fairly strong returns. Turn off any automatic attenuation and automatic tracking. For best results, minimise the time taken to perform each measurement.

Step 1: Find the beam centre

- i. Find the satellite and optimise the return rate to get an initial estimate of centre position
- ii. Scan in azimuth to find the signal boundaries (offsets required to extinguish signal)
- iii. Centre in azimuth and repeat for elevation.
- iv. Centre the beam on the satellite.



Step 2: Scan for the beam half-angle

From the centre position determined in step 1:

- i. Scan in azimuth to the signal boundaries and record angular offsets.
- ii. Repeat for elevation.
- iii. Record the satellite slant range and elevation

Step 3: Measure the signal energy reduction factor

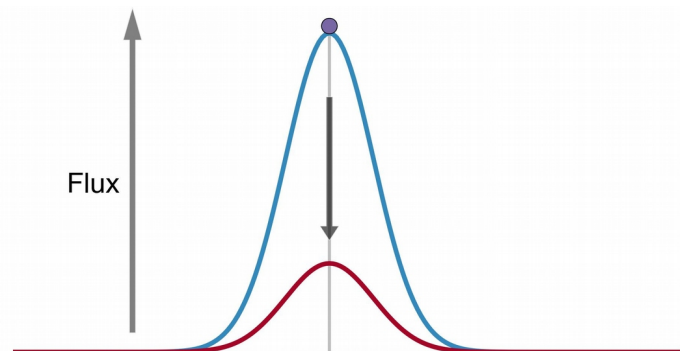
From the centre position determined in step 1:

If the laser energy can be modified:

- i. Record the full transmit power, E_{MAX} .
- ii. Reduce laser transmit power until signal is extinguished, record E_{MIN} .
- iii. Reduction factor F is E_{MIN}/E_{MAX} .

If using neutral density filters in receiver optics:

- i. Insert ND filters until signal is extinguished, record ND attenuation as reduction factor F .



Some practical factors to consider

- Real world conditions will introduce variations in the measurements. Pressure, humidity, local seeing, the proximity of the Sun, human error, target cross section, thermal gradients and laser performance will all impact on the result. It is advisable to perform the experiment swiftly and take an average value of several measurements at about the same elevation.

- When reducing transmit power on a flashlamp pumped system, do not reduce power by decreasing the capacitor bank charge voltage since this will reduce the lamp pump energy. A decrease in lamp pump energy will reduce the thermal loading of the laser medium and change the divergence. The transmit power can be reduced by changing the timing of the laser pulse transit with respect to the flashlamp pulse timing so that the laser pulse experiences less gain.

Further measurements

Once the scan procedure has been used to determine the divergence at a given setting, θ_1 , the beam divergence can be increased or decreased and a new divergence measurement made.

For the new beam setting, the transmit power (or ND filter transmission value T_{ND}) should be adjusted again to obtain the new signal extinguished point while the beam is still centred on the satellite. This allows determination of θ_2 from θ_1 from the following equation:

$$\theta_2 = [(T_{ND,2}/T_{ND,1})\theta_1^2]^{1/2} \quad \text{or} \quad [(E_{MIN,2}/E_{MIN,1})\theta_1^2]^{1/2}$$

This should only be used after θ_1 is well characterized since errors in θ_1 propagate to θ_2 . This allows for the quick determination of large divergence values, θ_2 . See *Burris et al, 2013* for more details.

Data Recording

Stations should maintain their own records of divergence measurements and also send the data to the Networks and Engineering Standing Committee in the format suggested below, email Matthew Wilkinson matwi@nerc.ac.uk. The data will be used by the NESCS and distributed to the other working groups of the ILRS as appropriate.

DATE/TIME (UTC)	SATELLITE	HALF AZ WIDTH	HALF EL WIDTH	RANGE	ELEVATION	FULL POWER	LOW POWER OR ND FILTER

References

Burris R. et al., *Proposed beam divergence estimation procedure for the ILRS. 18th ILRS Workshop, Tokyo, Japan, 2013.* (<http://cddis.gsfc.nasa.gov/lw18/docs/papers/Session8/13-03-06-Burris.pdf>)

Davis M. et al., *Beam Divergence: Introduction, results of measurements. 17th ILRS Workshop, Bad Kötzing, Germany, 2011.* (http://cddis.gsfc.nasa.gov/lw17/docs/presentations/session10/01a-Session10_DavisDivergence.pdf)