Dynamic Alignment of Transmission Telescope

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Motivation

Integrated Radio Optical Communication Satellite designed to transmit data between Mars and Earth.

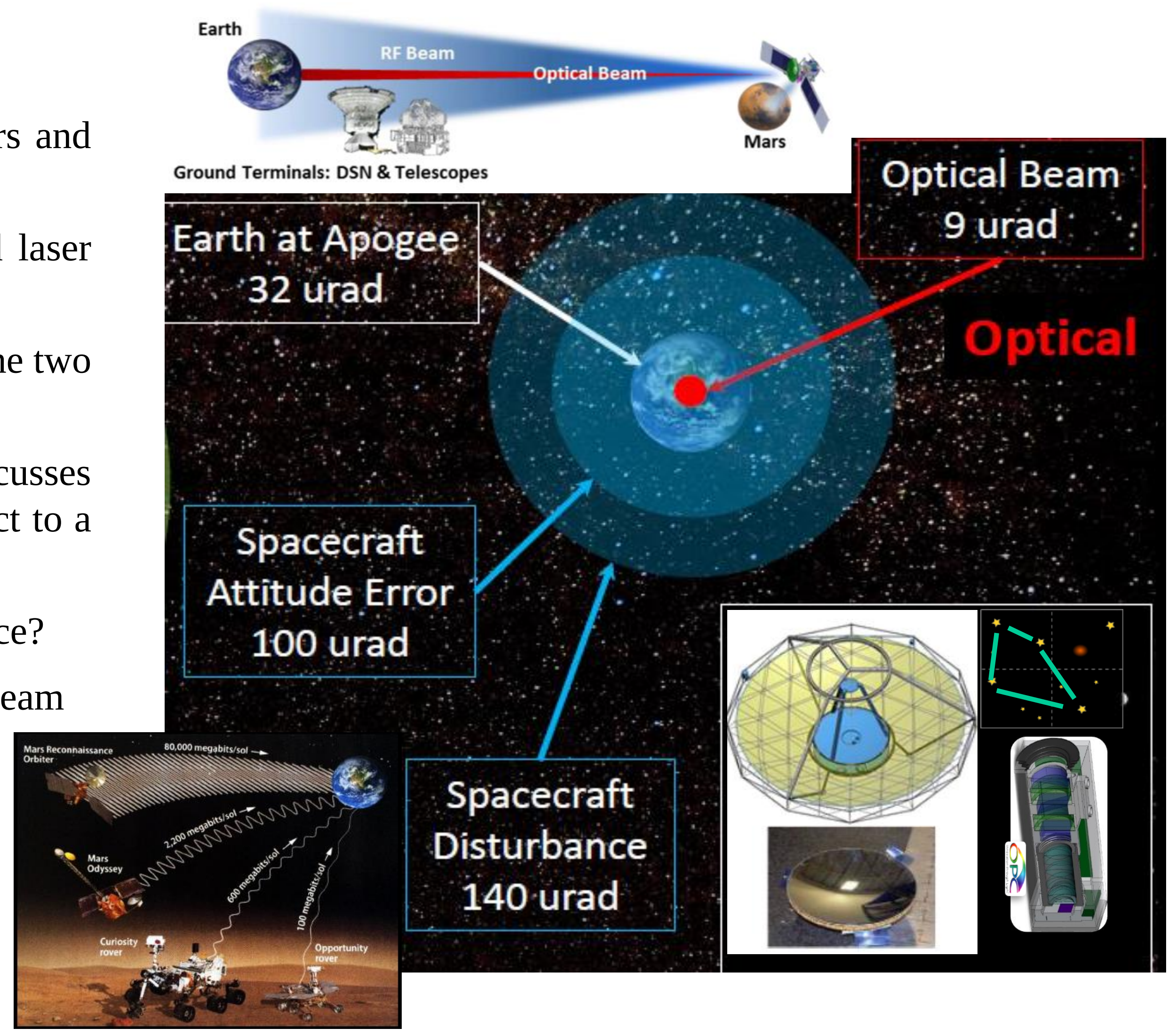
Communication is accomplished by means of radio waves at 32.67 GHz (Ka Band) and laser beam at 1550 nm, both transmitted via a teletenna.

Considering the spatial distances, beaconless precision pointing is necessary to insure that the two terminals (on Earth and Mars orbiter) are communicating with each other at the fastest rate.

The experiment presented simulates this communication in laboratory setting and discusses indirect measurement techniques of the angular displacement of the laser beam with respect to a reference point.

Question 1: How can we determine the quality of the transmitted beam profile and divergence?

Question 2: How can we accurately determine and control the relative position of the laser beam with respect to a reference star?



Proposed solution

The process requires external alignment between the telescope and the receiver placed on Earth (also referred to as pointing precision) and the internal alignment by means of fiducials placed along the beam path.

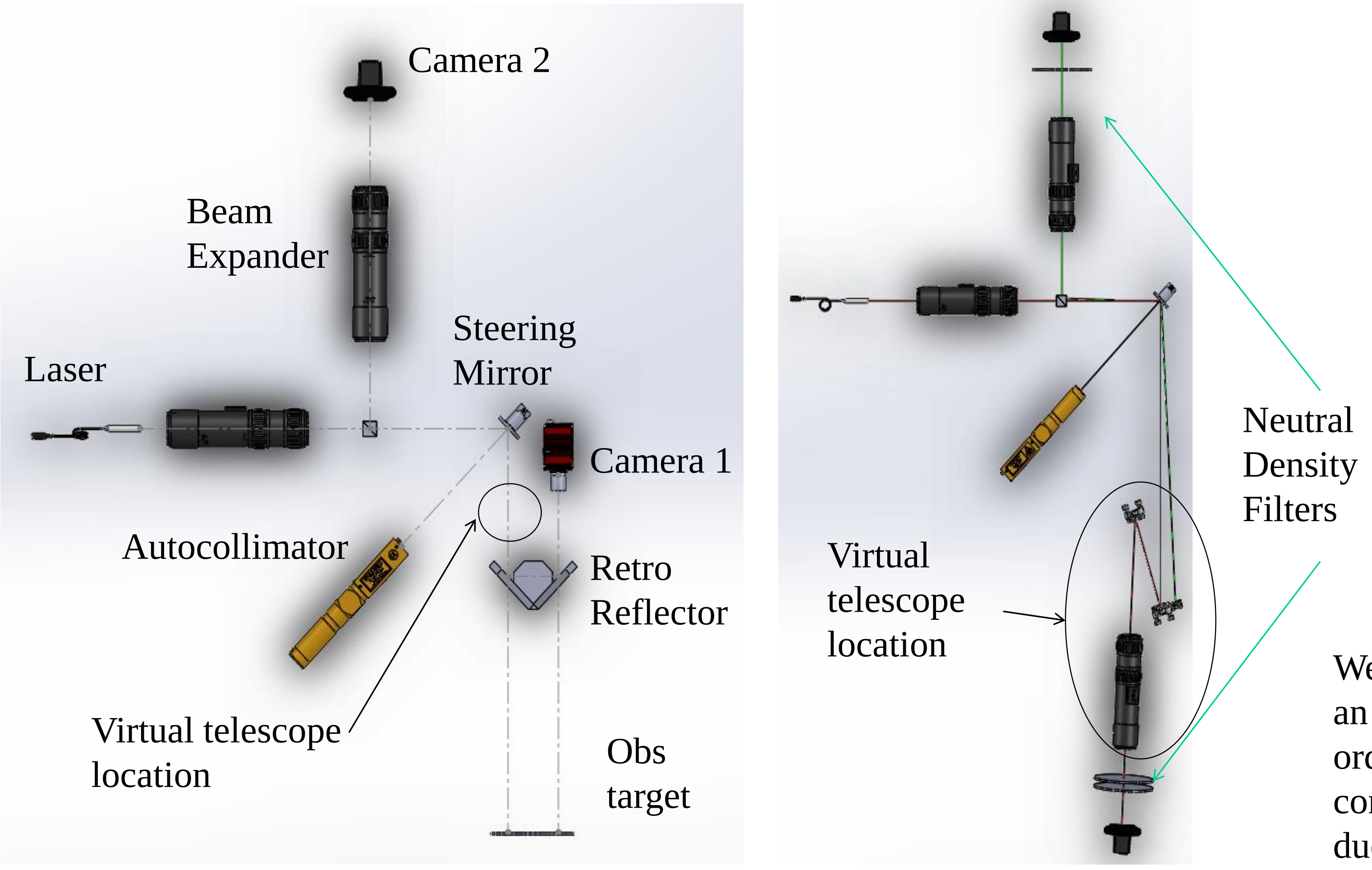
The external alignment is ensured via the ST, which detects the position of the astral bodies, and based on celestial calculations, it determines with accuracy the position of the laser beam (LB) with respect to the Earth at the moment of transmission. Due to the lack of need for a beacon in the iROC system the 'point ahead' function is reduced to a simple 'deflection shooting' calculation.

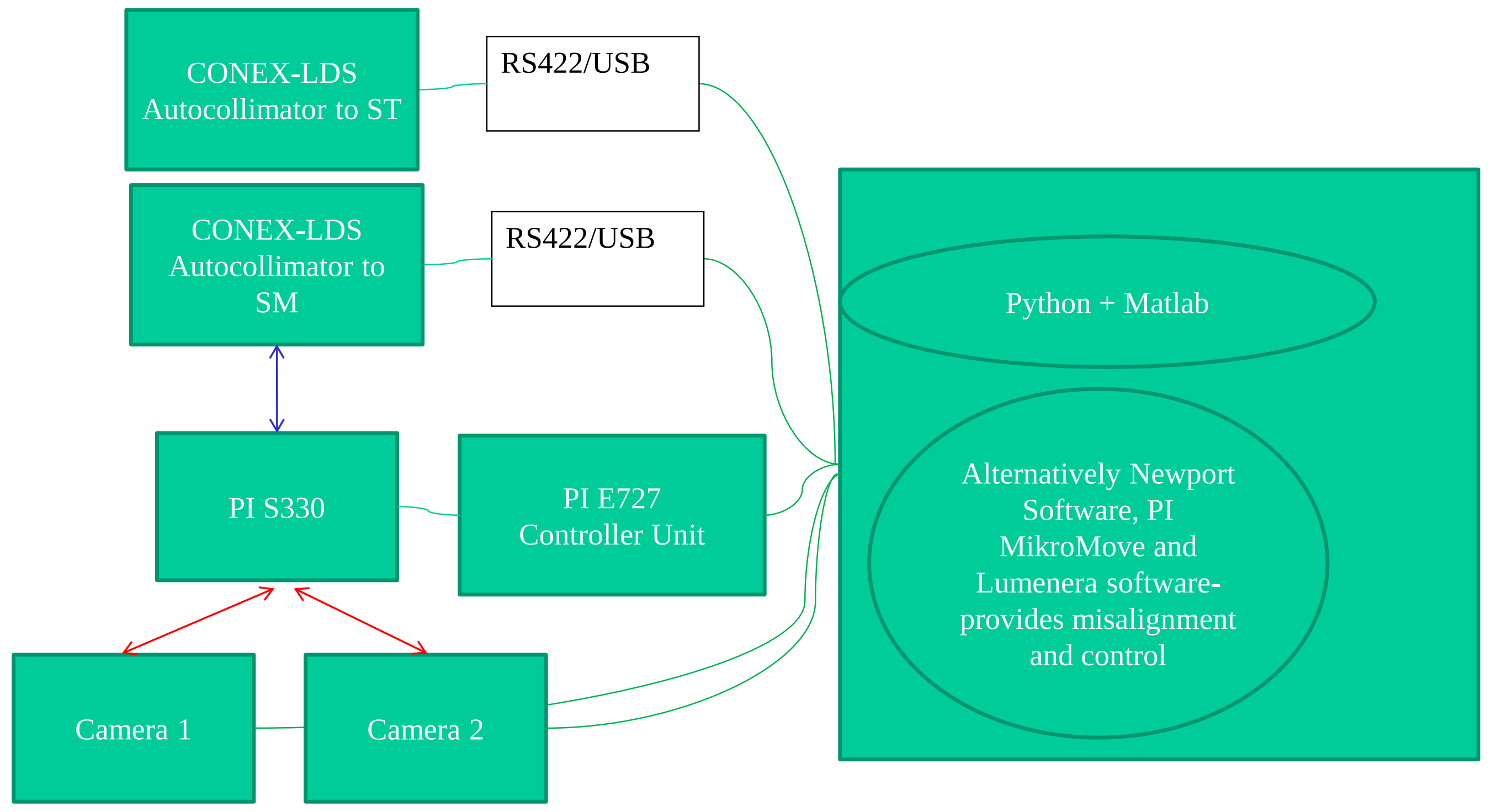
Limitations on the optical field-of-view for the telescope, brought by the need to simultaneously detect the Earth beacon and pass the communications beam are, thusly, eliminated.

For the internal alignment, we propose a combination of an alignment pixelated sensor (PixSens), placed behind the primary mirror of the telescope, in combination with the ST sensor, which is placed outside the telescope.

In this proof of concept, we used a simplified design of the telescope.

The alignment principles are based on the claim that a relative change of the outgoing laser beam partially captured (via a corner cube) by ST is strongly related to the relative change in the position of a reference beam reflected off the secondary mirror into the PixSens which already detects a portion of the laser beam on its way to the fine steering mirror. This relation is mathematically derived based on measurements of these relative positions and their nonlinear interdependence




CONEX-LDS Autocollimator to ST

RS422/USB

CONEX-LDS Autocollimator to SM

RS422/USB

Python + Matlab

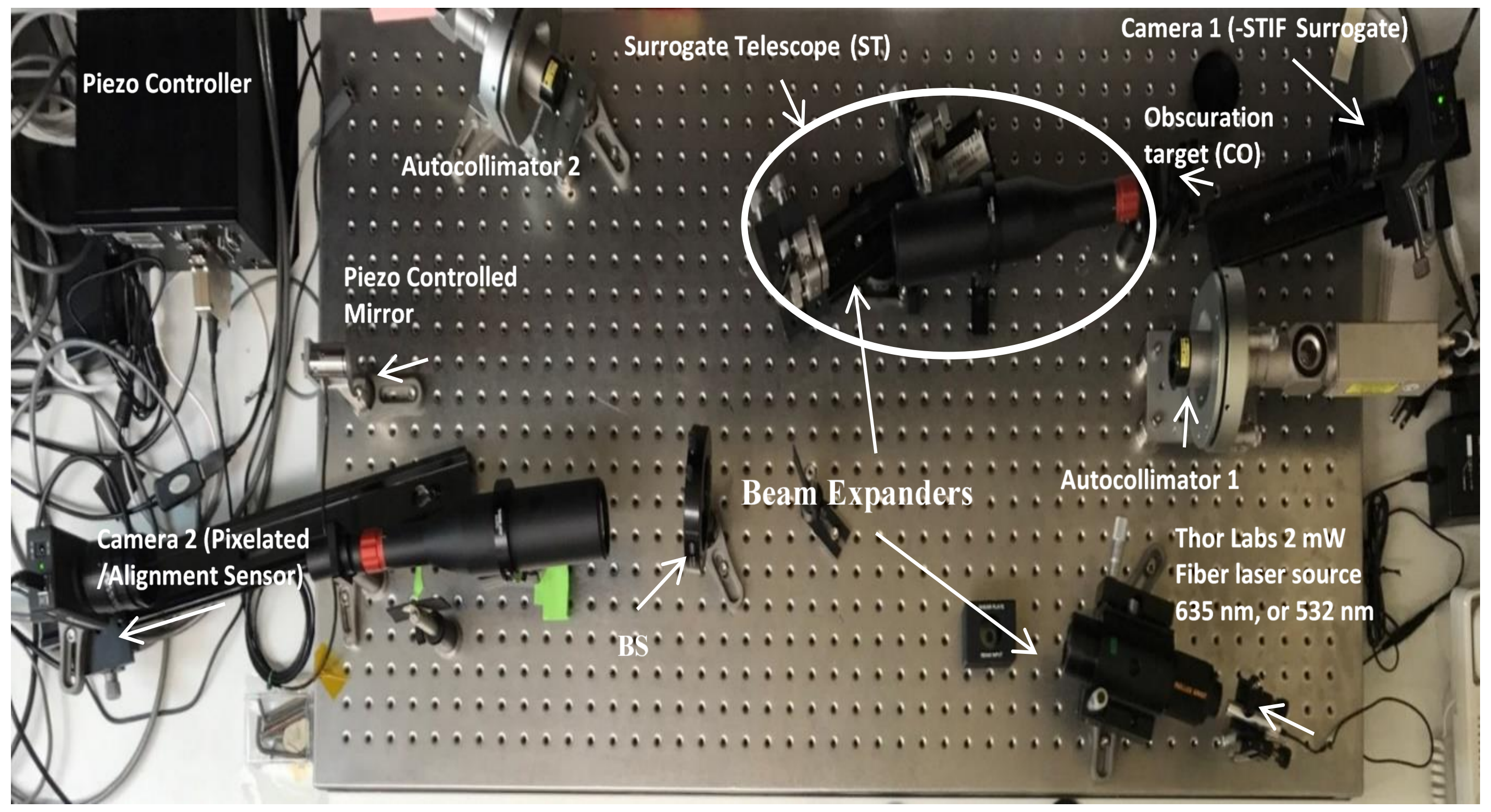
Alternatively Newport Software, PI MikroMove and Lumenera software- provides misalignment and control

PI S330

PI E727 Controller Unit

Camera 1

Camera 2



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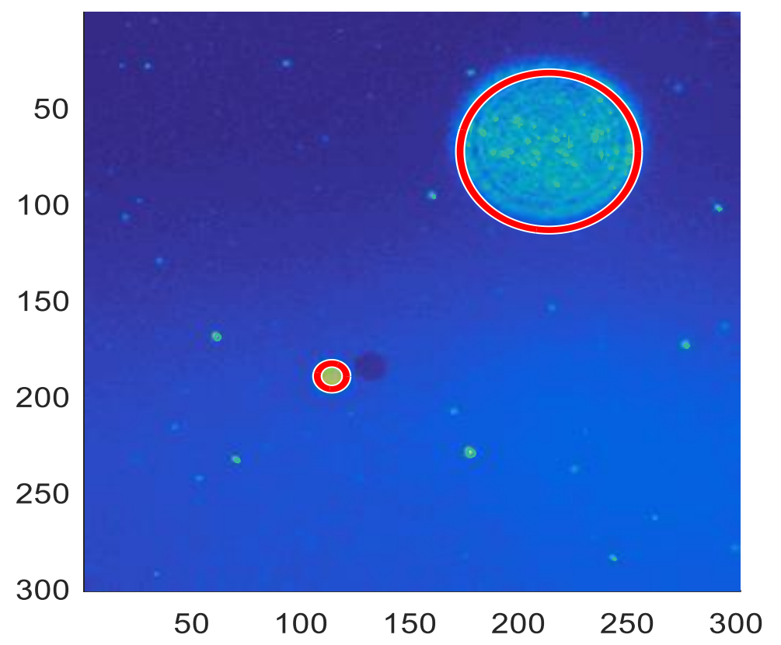
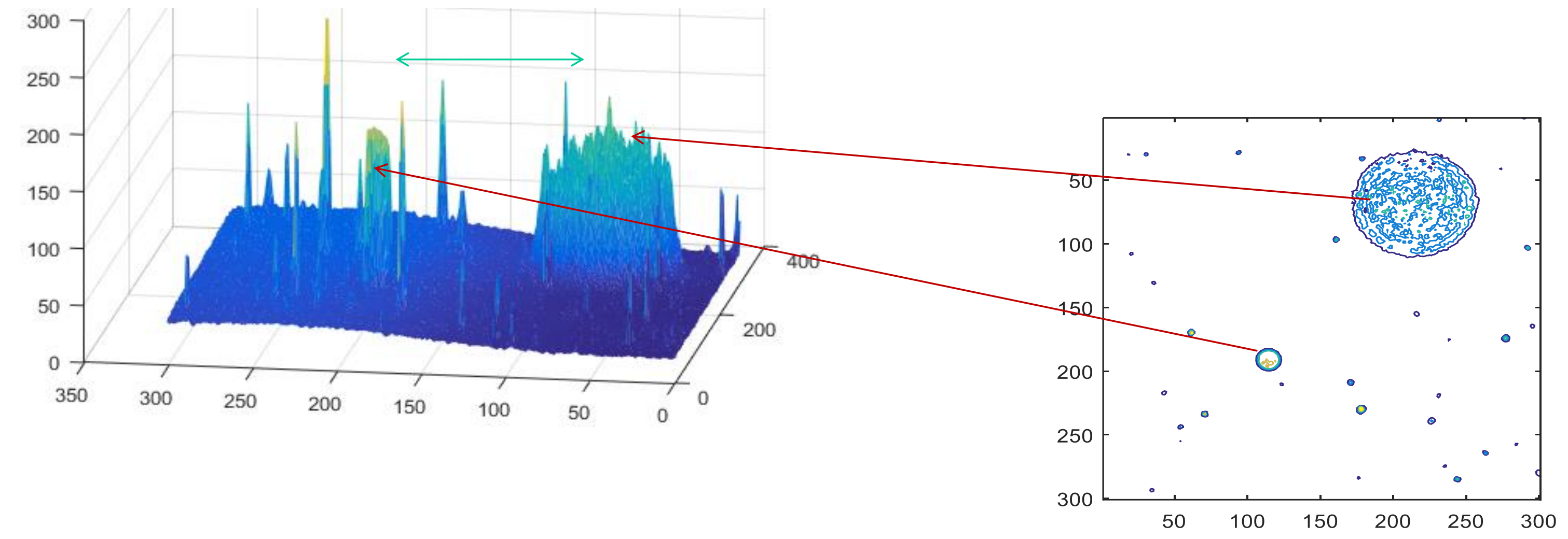
Simulation Analysis

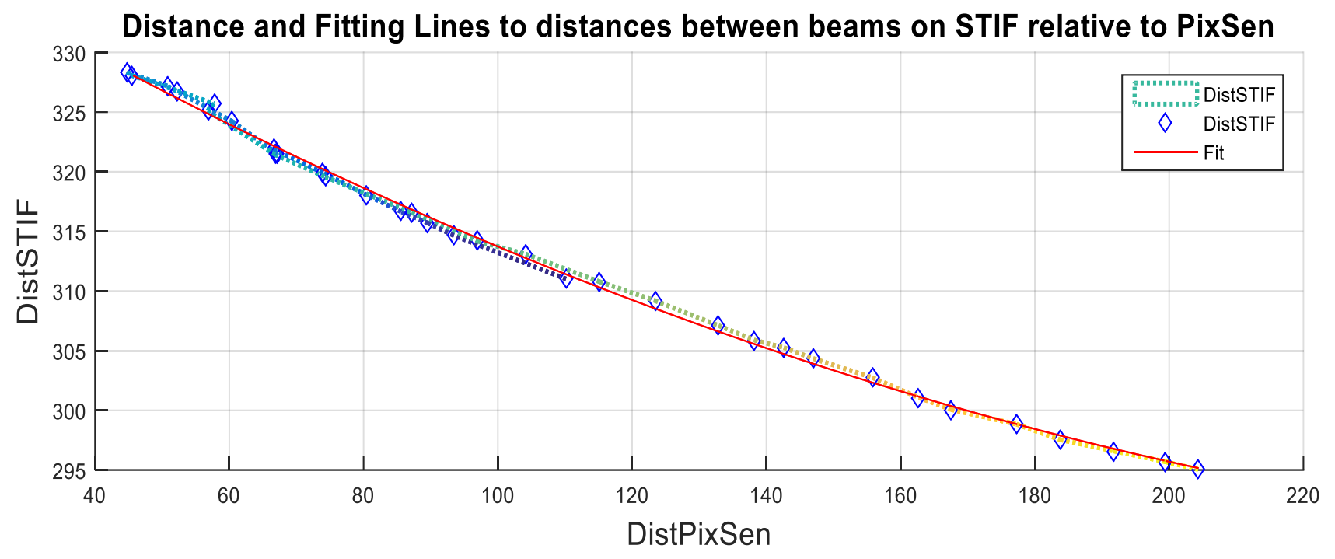
Centroid		MajorAxisLength	MinorAxisLength
213.7981	73.0673	94.5702	68.9076
114.0000	189.9000	14.4937	12.2164



L_S_dist = 153.6539 px



Results


Distance and Fitting Lines to distances between beams on STIF relative to PixSen

DistSTIF=280.26987+
+0.00028294*Dist_PixSen_Squared
+0.02671*PiPosX

M#	C(p)	R-Square	Adj. R-Sq	BIC	Variables in Model
5	5.241	0.9998	0.9997	-107.98	DistPixSens DistPixSensSquared DistPixSensCube DistPixSensQuad PiPosX

We showed that a model based on the FB–-FP square distance and FSM performs with an R-sSquared of 0.9997 and an aAdjusted R-sSquared of 0.9996. Adding more variables is not justified at this point. A model based on higher-order terms of the FB–-FP distance on PixSens and all other variables is equal or less than 99.98 percent, which concludes that adding more variables does not improve the regression and requires an increase in power and weight due to the added metrological instruments on the payload.

Conclusions and Acknowledgements

- Among other findings, the work presented here shows that the alignment measurements performed at the edge of the Fine Steering Mirror (FSM) articulation range lead to nonlinearity in the relationship between the out-going beam direction registered on the iST and the fiducial reflected beam direction on an alignment sensor placed behind the telescope.
- For this reason, the adjustment of FSM angular position can realign only one of the beams with its respective camera but not both, and therefore an additional metrology instrument is required for high pointing precision.
- In the presented proof-of-concept metrology, this additional metrology component could be the piezo-controller of the FSM and/or an autocollimator that gives with accuracy the position of the FSM. These findings are relevant to the current development and design of the iROC system at GRC.
- Angular dependence of the centroids on the receiving camera is to be determined with respect to piezo controlled steering mirror.
- Simulations in the indirect measurement procedure are necessary to cover multiple case scenarios.
- Real time Instrument interface is necessary for triggering and simultaneous measurements

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