LIDAR Thomson Scattering for STEP

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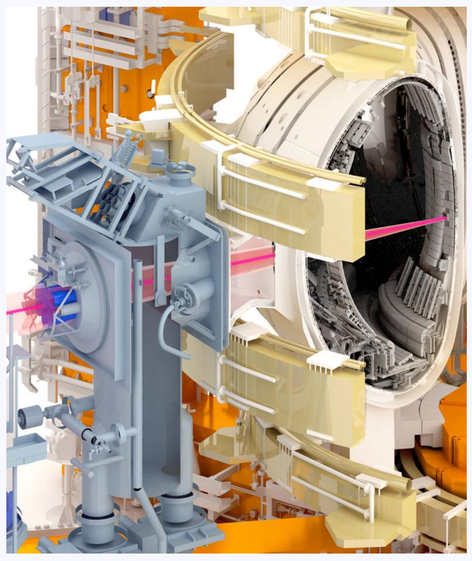
LIDAR Thomson Scattering

- Plasma diagnostic which combines Thomson Scattering and LIDAR ranging techniques
- Ultra-short laser pulses
- Position in plasma from the time-of-flight delay
- Only relatively simple access to the plasma required
- Has been operated by UKAEA at JET for ~40 years [1-3]
- Not implemented on any other machine (yet) but was considered for ITER [4-6]

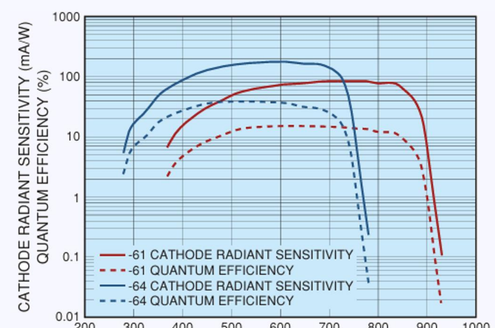


LIDAR at JET

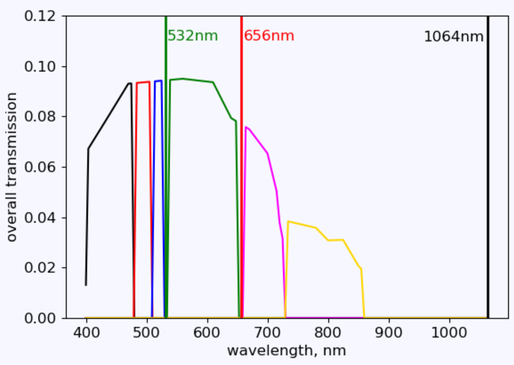
STEP LIDAR Proposal

- Dual laser 532nm E=3J, 1064nm E=5J, t=300ps [7]
- MCP-PMT detectors, GsAsP+GaAs – same as used on JET in 2011-2023 [2]
- 10cm first wall aperture, 20cm first mirror diameter
- 2 first mirrors – Rhodium [8,9]
- Spatial resolution ~8cm

Detectors spectral response

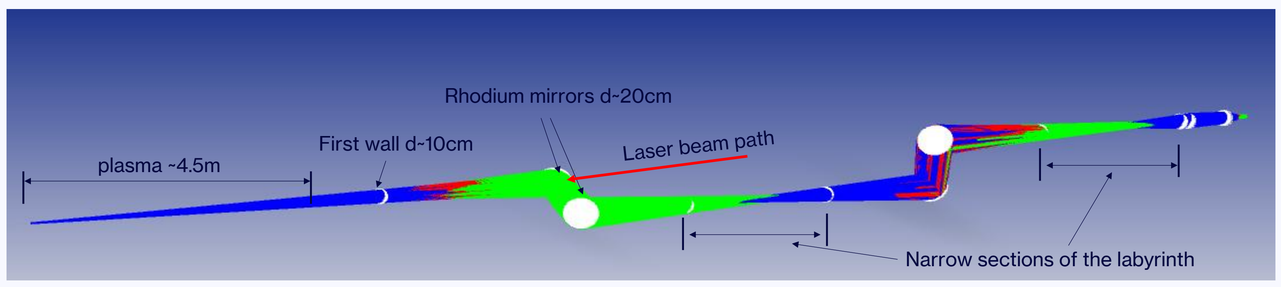


Spectral channels configuration

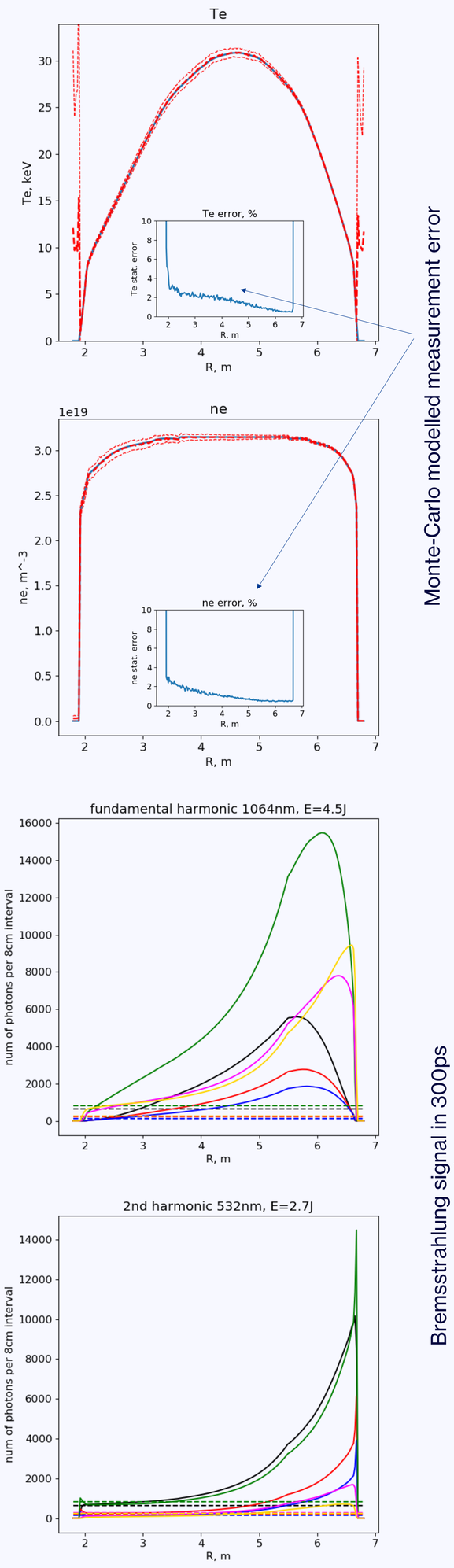


Performance analysis

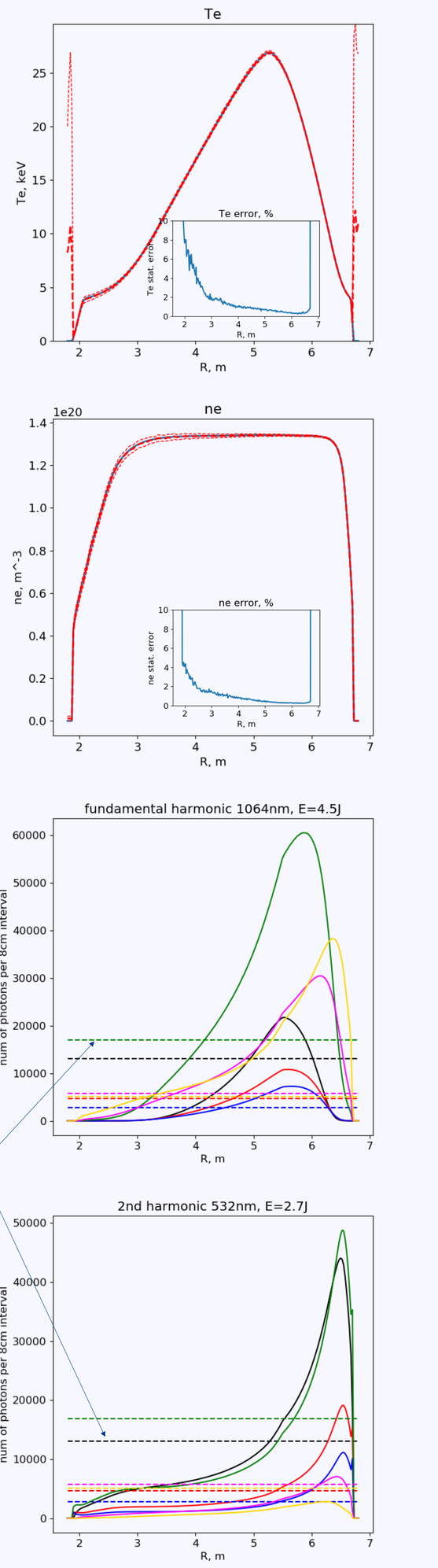
- Ramp-up and flattop scenarios modelled
- Bremsstrahlung x2 for reflections and line emission
- 10% E_{las} loss in the transmission
- Light collection: double Rhodium mirror and 20 surfaces 2% loss each
- Collection solid angle changes with radial position



Ramp-up scenario



Flattop scenario



Monte-Carlo modelled measurement error

Bremsstrahlung signal in 300ps

Dual laser self-calibration

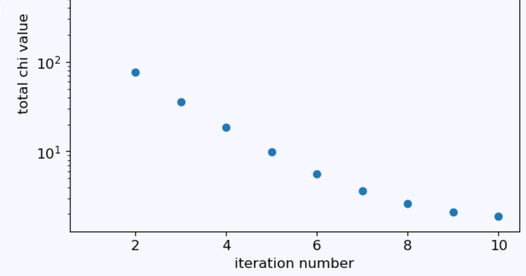
- T_e and n_e derived from the best fit between the measured and expected signals in each spectral channel
- $R_i = n_e F_i(T_e) - S_i$ <= discrepancy between fitted and measured signals
- In the absence of systematic errors $\langle R_i \rangle = 0$
- In case of calibration errors, $\langle R_i \rangle \neq 0$ and depends on T_e

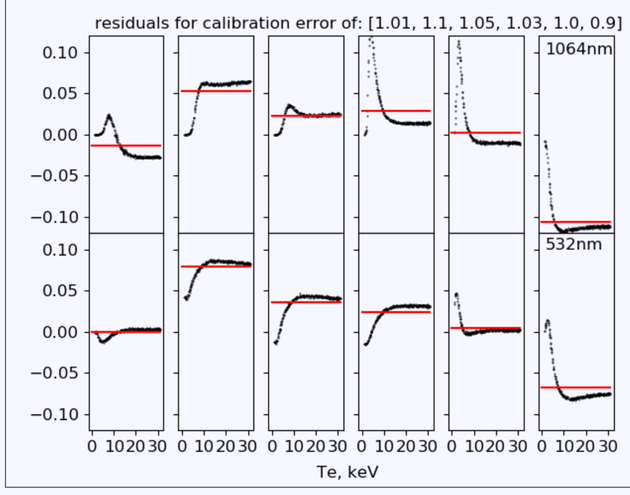
1064nm laser 532nm laser

$$\chi^2_{tot} = \sum_j \sum_i w_{1,i} \left(n_{e,j} F_{1,i}(T_{e,j}) - \gamma_i S_{1,i}\right)^2 + \sum_i w_{2,i} \left(n_e \gamma_0 F_{2,i}(T_{e,j}) - \gamma_i S_{2,i}\right)^2 = min$$

Systematic calibration error, same in all the measurements

- χ^2_{tot} - total discrepancy between fitted and measured signals in a large dataset
- Finding the minimum of χ^2_{tot}: $d\chi^2_{tot} / d\gamma_i = 0$
- Must do it iteratively since T_e and n_e depend on γ_i: recalculate T_e and n_e in each step
- In simulations the process quickly converges to correct pre-defined calibration error





Conclusions

- Initial design work for STEP LIDAR Thomson Scattering proposal is ongoing.
- The design uses a dual colour scheme based on fundamental and 2nd harmonic Nd:YAG lasers and the type of detectors previously implemented and demonstrated at JET.
- We are exploring whether the diagnostic could provide T_e and n_e profiles in the non-active (hydrogen) plasma phase and initial D-T phase up to the establishment of routine D-T operations.
- As former JET Operator (2000-2023), UKAEA possesses unique experience in operating LIDAR TS system on a tokamak

References:
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[7] www.expla.com
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