# Investigation of the Optical Design of Remote In-Situ Operations of Pipework in Future Fusion Power Plants

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Energy security is a worldwide issue, global electricity demand is forecast to increase by 150% by 2050 [1]. Both governments and private organisations are pursuing domestic alternatives to fossil fuels, including nuclear fusion. Fusion offers the potential to offer an inexpensive, inexhaustive and steady electricity supply from the fusing of deuterium and tritium in a confined plasma [2]. The extreme conditions for fusion (high temperatures, pressures and neutron fluxes) cause significant materials degradation to plasma facing components (PFC) and cooling and fueling interfaces, such as pipework. PFCs will need regularly replacing and will require cutting, joining and qualification of connecting steel pipe joints (316L and P91). The pipe joints are situated in irradiated space-constrained areas with low visibility, prohibiting human intervention inside the fusion device. Therefore, novel tools with safe and reliable remote maintainability are needed to carry out pipe maintenance tasks [3].

Researchers at the UK Atomic Energy Authority have prototyped a remote in-bore welding and cutting robot to replace pipe work. A laser package has been selected due to its multiple advantages; high productivity, minimal heat affected zone on parent material, reduced complexity (no filler wire addition), scalability across pipe sizes, non-contact process, dual modes of cutting/welding and potential as a pre- or post-weld heating process. In bore cutting, welding and weld face alignment were demonstrated at technology readiness levels (3-4), illustrating significant work is needed to develop this tooling further. One of the factors identified as requiring further investigation is the optical design to increase power handling capability and process control. Specifically an increase to allow welding of 3mm to 5mm pipe thicknesses, debris management and in-situ quality control on the tool [4]. This work explores alternative optical solutions to combat these issues, using modelling techniques and experimental verification.

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