Chapter 4

Modelling

Although the work of this project was primarily experimental, some modelling work was performed in order to better understand the physics of LSP and aid in the experimental design. One major area of interest is in determining the absorption properties of LSP. High laser absorption is desirable to maximize power conversion efficiency. Furthermore, the IB absorption coefficient typically reaches a maximum at a specific temperature. According to Keefer [22], this peak absorption temperature was found to closely correlate with LSP peak temperature. The measurement of absorption coefficient can thus be used to support LSP temperature estimates.

4.1 Absorption

A critical property of LSP is its ability to absorb laser radiation. As stated in Section 2.2, the primary mechanism for radiation absorption in LSP is inverse bremsstrahlung. Calculation of the absorption coefficient of this process is critical for modelling LSP behavior and estimating its laser absorption efficiency. The calculation method presented here aims to adapt the work of Akarapu *et al.* [60] and Nassar [61], who have developed CFD models for the use of Argon LSP in surface-treatment applications. Although their work considered CO_2 lasers, adapting the method to the fiber laser of this study is a matter of using the appropriate laser frequency in Equation 2.2. Their work was thus used to validate each calculation step, and their results will be plotted alongside this study's computations when relevant.

The absorption coefficient can be calculated using Equation 2.2 and is heavily dependent on electron density n_e and radiation frequency ν. The first step of absorption modelling is thus to determine electron density, which is variable with temperature T according to the Saha ionization equation, developed by Saha and Fowler [62]. It is reproduced here for the single ionization case as Equation 4.1:

$$\frac{n_e^2}{n_0 - n_e} = \frac{n_e^2}{n_{Ar}} = \frac{2}{\Lambda_{th}^3} \frac{\mathcal{Z}_{Ar^+}}{\mathcal{Z}_{Ar}} \exp\left(-\frac{E_{ion,\,Ar}}{k_B T}\right) \tag{4.1}$$

Where n_0 is the initial number density of neutral atoms, n_{Ar} is the number density of un-ionized atoms at a given temperature, $E_{ion,\,Ar}$ is Argon's first ionization energy (15.76 eV [63]), and k_B is the Boltzmann constant. The thermal DeBroglie wavelength Λ_{th} is a function of