

## Abstract

This Doctoral Dissertation investigates Quasi-Simultaneous Laser Welding (QSW) as an advanced joining technique for thermoplastic polymers in industrial applications. Other conventional and competitive polymer welding methods are critically reviewed, and their limitations in terms of cleanliness, design flexibility, and cycle time are discussed. To overcome these constraints, a dedicated diode-laser system with galvanometric scanning was designed, built, and validated to enable precise control of energy delivery and to experimentally explore the QSW process window. A comprehensive experimental campaign systematically varied key process parameters (laser power, scanning speed, and number of scan repetitions) on material pairs such as PMMA–ABS (both T-joint and overlap configurations) and PA66–PA12. In the specific study on PMMA–ABS joints in T-joint configuration, using a circular wobble path, linear energy density emerged as the critical descriptor linking process inputs to weld quality. This enabled the identification of process windows that produced penetration depths of approximately 1 mm and tensile strengths up to 12.58 N/mm, while keeping welding cycle times below 1 s, fully compatible with industrial mass-production requirements. Within this framework, QSW showed clear advantages over contour welding, delivering more robust processing conditions, cleaner weld seams, improved hermeticity, and greater tolerance to geometrical variability, in line with recent literature on laser transmission welding of polymers. The same methodology was subsequently validated in the PowerPack project, which involved the development of an alternative battery-pack architecture in which conventional all-metal enclosures were replaced by thermoplastic components, specifically LATAMID 66 H2 G/30 and LATICONTHER 62 CP6/650-V0HF1, assembled by means of the QSW process. Overall, the thesis establishes QSW as a reliable and scalable technology for high-volume polymer assembly, defining practical process windows that balance weld strength, cycle time, and energy efficiency. Future efforts should integrate real-time thermal monitoring and multi-physics simulations to further enhance process control and support broader industrial deployment.