High-speed synchrotron X-ray imaging of the melt flow during laser beam welding of high-alloy steel

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Introduction:

Stainless steels have a wide range of technical applications due to their good weldability and corrosion resistance. Using laser beam welding an increase in laser power enables higher welding speeds for manufacturing processes with these steels, however, higher welding speeds favor the formation of weld seam imperfections. The use of intensity distributions has already been proven to reduce seam imperfections, in particular spatter formation. The superposition of a main intensity with a second intensity enlarges the melt pool during the welding process and reduces the flow speed of the melt surrounding the keyhole. However, a detailed description of the melt flow with a superposition of two intensities is not given yet.

Experimental setup:

The bead on plate welds described were performed on vertically aligned austenitic steel AISI 304 sheets with a thickness of 2 mm (see Fig. 1) using a disk laser (Trumpf TruDisk 8001) with a wavelength of 1030 nm. The power of the main laser was set for a welding depth of 1.5 mm. A second diode laser beam source (LDM3000) influenced the melt pool around the keyhole. The powers of the second beam source were set to 0, 1000 and 2000 W.

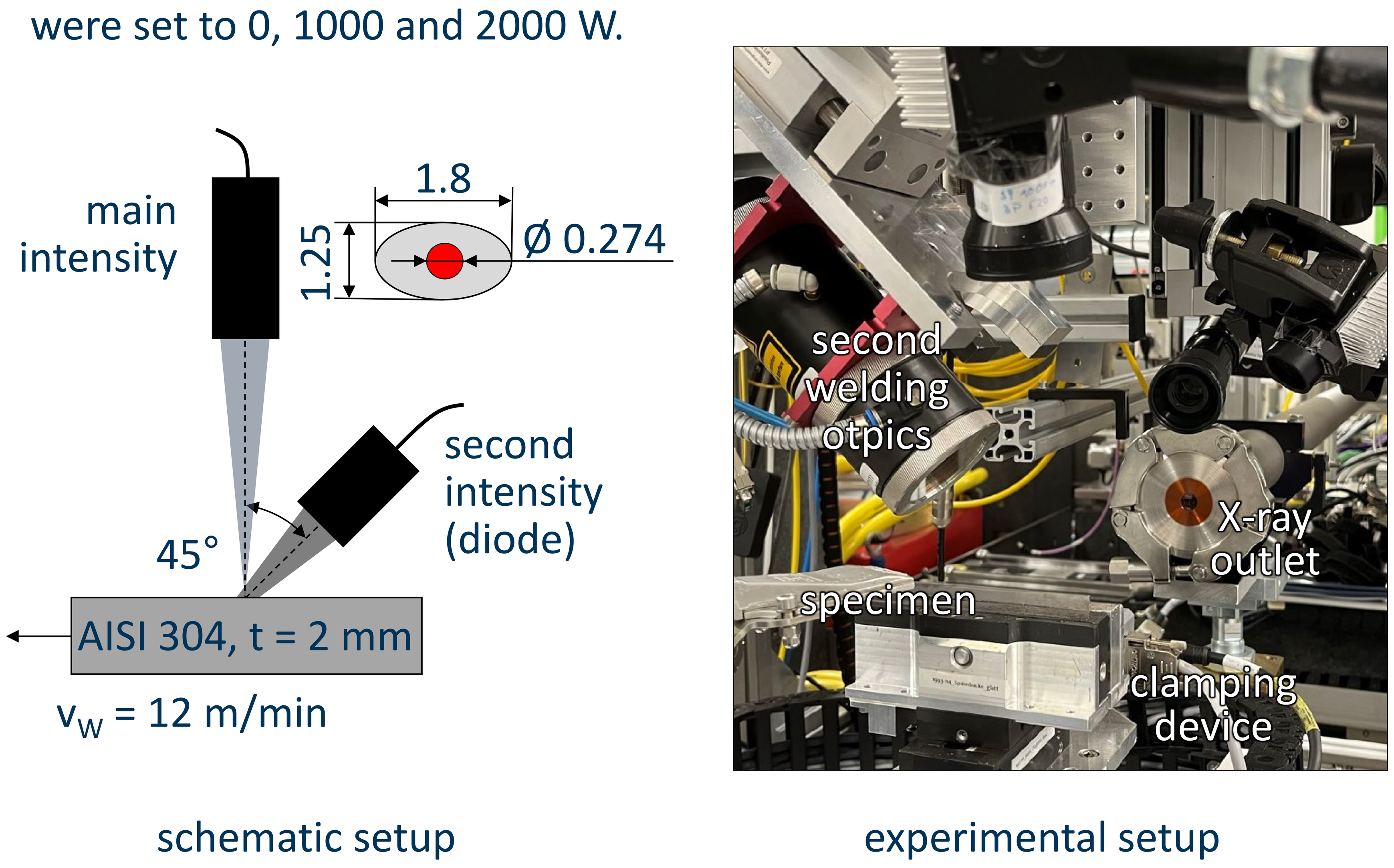

Fig. 1: Illustration of the schematic and experimental setup

The experiments were performed at Petra III at DESY (Deutsches Elektronen-Synchrotron). High-speed synchrotron imaging at a frame rate of 10,000 Hz visualized the keyhole behavior. In addition, the use of tungsten carbide particles ranging in size from 60 to 190 µm visualized the melt flow. The particles were inserted into the melt pool and three positions and were tracked during a weld time of 20 ms.

Data processing:

The recorded high-speed images were pre-processed for the process evaluation. The original images were divided by an averaged image without welding process (see Fig. 2).

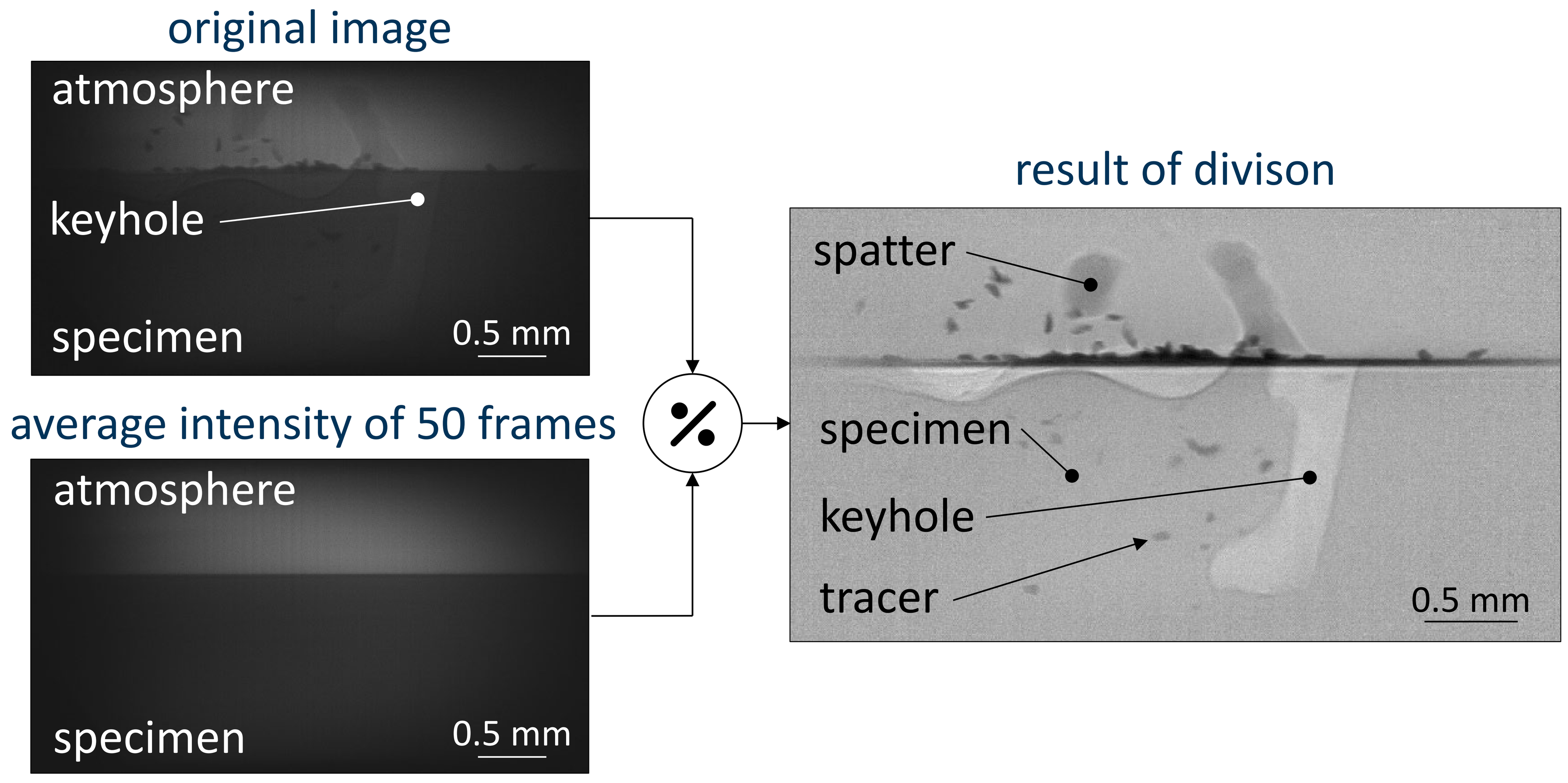

Fig. 2: Image processing of an exemplary frame of the high-speed synchrotron X-ray images

Results & Discussion:

The melt flows for the different diode laser powers were compared to gain a better understanding of the process behavior. For this purpose, the determined movements of the tracers are displayed as vectors for each of the diode laser powers. The background image represents the keyhole behavior as an image stack with minimum intensity projection (see Fig. 3).

The melt flow is divided into two areas. The melt flows directed against the welding direction at the keyhole bottom (area 1). In addition, the melt flows upwards at the keyhole rear wall (area 2). The diode laser with a power of 2000 W suppresses this flow due to a modified keyhole geometry.

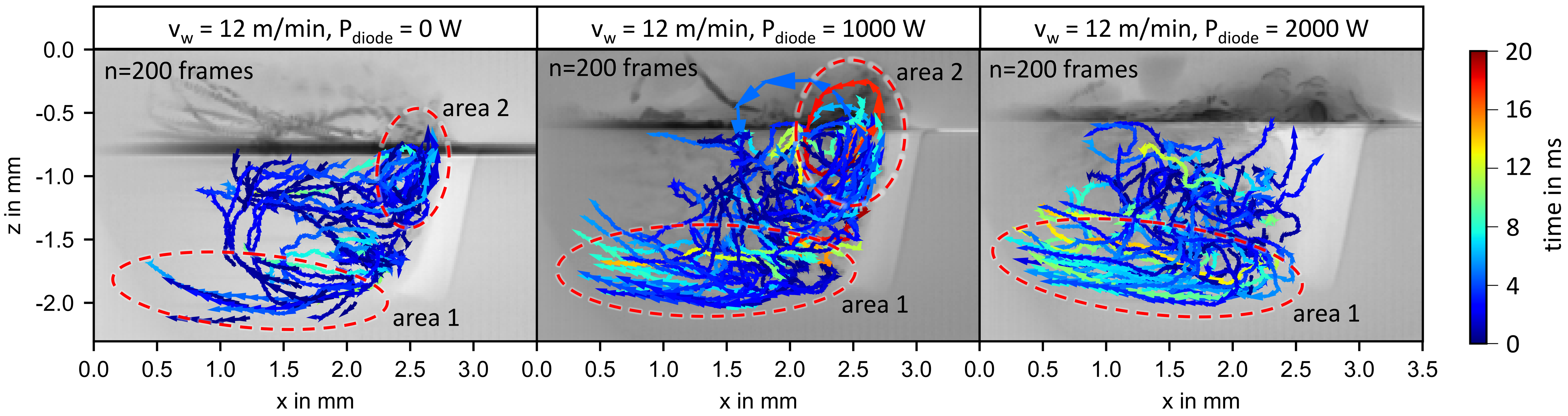

Fig. 3: Analysis of the melt flow based on the movement of the tracers for different diode laser powers

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