Introduction
The study presented here is a preliminary work on titanium laser welding. Its main objective is to investigate the possibilities offered by the in-situ characterization methods available in EMPA in order to evaluate what kind of correlation could be drawn between the characterization measurements and the weld quality. In order to do so, a welding set-up has been developed to investigate what are the influences of the main experimental parameters on the weld quality.

Materials and Methods

Welding set-ups
First experiments in open atmosphere under argon shroud. Precise control of the atmosphere surrounding the sample needed - development of a welding chamber.

- Open atmosphere
- Welding chamber

Results:
Effect of laser peak power
under argon shroud in open atmosphere

Increasing power:
- Gradual coloration
- Increased: 
  - Coloration zone size
  - Penetration depth
  - Hardness

Due to:
- Higher heat input:
- Increased penetration depth
- Lower cooling rate
- More time for O and N contamination
- Solid solution hardening

In-situ characterization methods

- Mass Spectrometry (MS)
  - Composition of atmosphere around the weld
- Optical Emission Spectroscopy (OES)
  - Emission spectra of the plasma
- High Speed Camera (HS cam)
  - Behavior of the plasma plume (duration, expansion, brightness...)

Effect of laser peak power
under argon shroud in open atmosphere

HS cam:
- Power increase:
  - Brighter plasma
  - Longer plasma duration
- OES:
  - Same shape
  - Peak broadening and/or overlapping
  - No line identification

Air contamination in welding chamber

Increasing air content:
- Gradual coloration
- Increased hardness
- Similar microstructure

Due to:
- Increased oxide layer thickness
- O and N solid solution hardening

Conclusions
Weld quality
- Penetration depth determined by laser power
- ~200 μm: achieved at 1.1 kW
- Weld coloration governed by air contamination in atmosphere around the weld
- No coloration: achieved in welding chamber (1% air)
- Weld hardness governed by air contamination: solid solution hardening
- ~175 HV: achieved in welding chamber (1% air)
- Further decrease in weld hardness: Higher atmosphere control needed

In-situ characterization methods

HS cam
- Qualitative information on:
  - Plasma shape
  - Plasma emission duration

OES
- High air content:
  - Broad peaks / No line identification
  - Overall intensity related to air content
- Low air content (1%):
  - Exploitable spectrum acquired
  - Line identification possible

Outlook
Further optimization of welding chamber (new design) → reach higher atmosphere control during welding
- Lower air contamination
- Less O and N solid solution hardening of the welds
- Acquiring OES spectra allowing spectroscopic measurements (Plasma composition and temperatures calculation)
- Investigation of different shielding gases

Materials and Methods

Samples
- Material: Commercially pure Titanium Grade 2 sheets
- Thickness: 300 μm
- Surface finish: sandblasted

Laser
- Nd:YAG pulsed laser
  - SLS 200 C60 from Lasag
  - λ: 1064 nm
  - Spot size: 600 μm

Parameters
- Fixed pulse length, pulse frequency and welding speed
- Pulse power: 0.9, 1.1 and 1.3 kW
- Welding type: Bead on plate