welding data exchange
open science initiative

BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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WELDX – A FILE FORMAT FOR PROCESSING AND ARCHIVING WELDING RESEARCH DATA

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introduction
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www.bam.de/weldx

https://github.com/BAMWelDX/weldx

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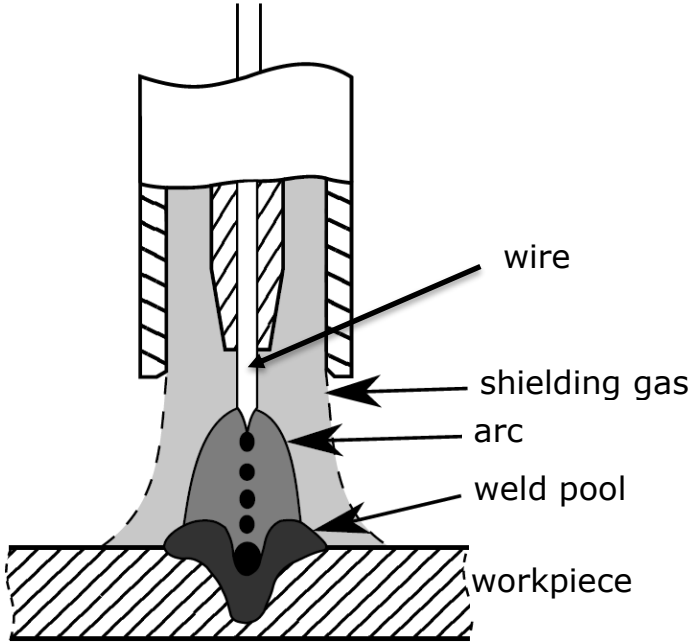
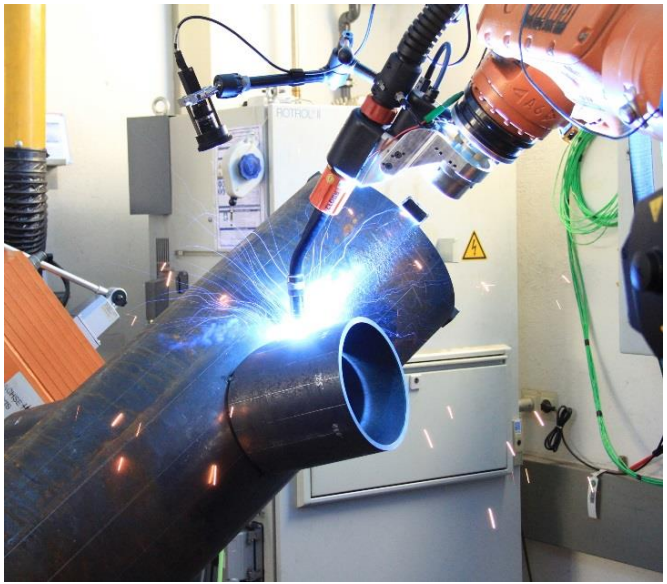
- BAM research associate since 2014
- **background in welding applications and control**
- **“I like doing RDM because I need it.”**

➡ **Build the tools we want to use !**

introduction
Gas Metal Arc Welding (GMAW)

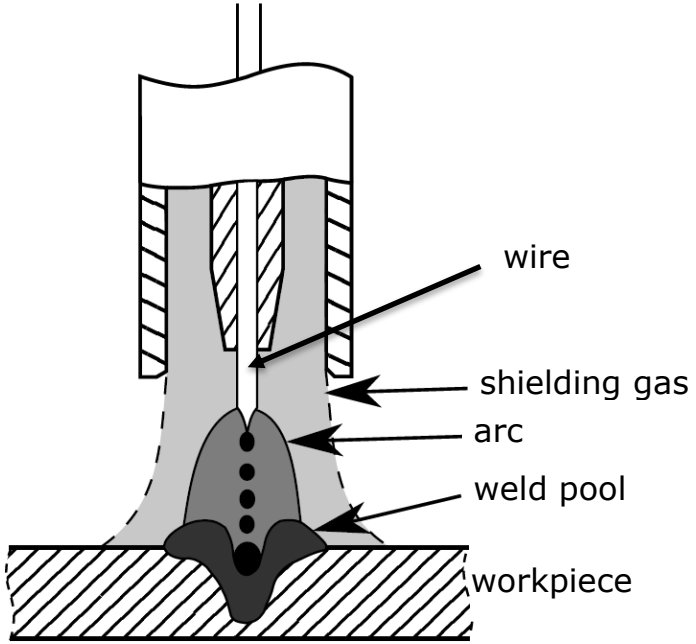


GMAW principle

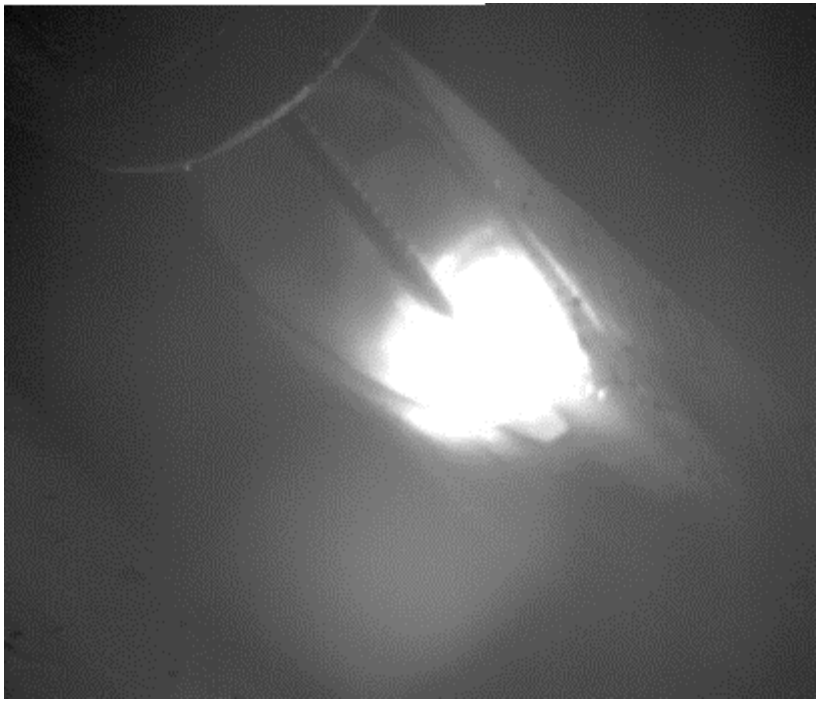


automated GMAW

introduction
Gas Metal Arc Welding (GMAW)

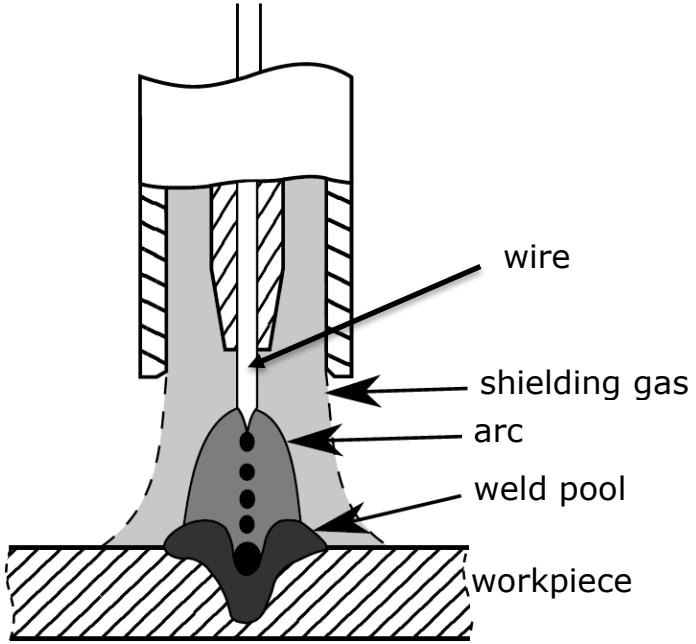


GMAW principle

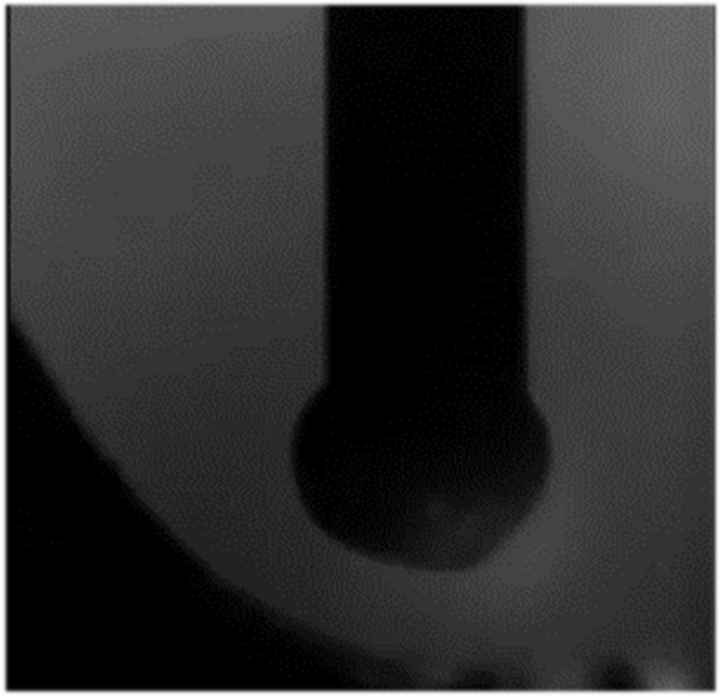


HDR recording

introduction
Gas Metal Arc Welding (GMAW)



GMAW principle



highspeed recording

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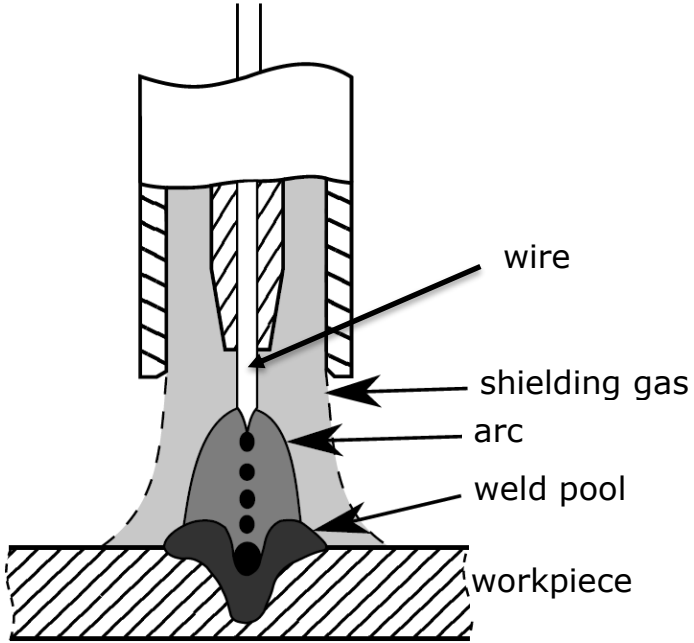
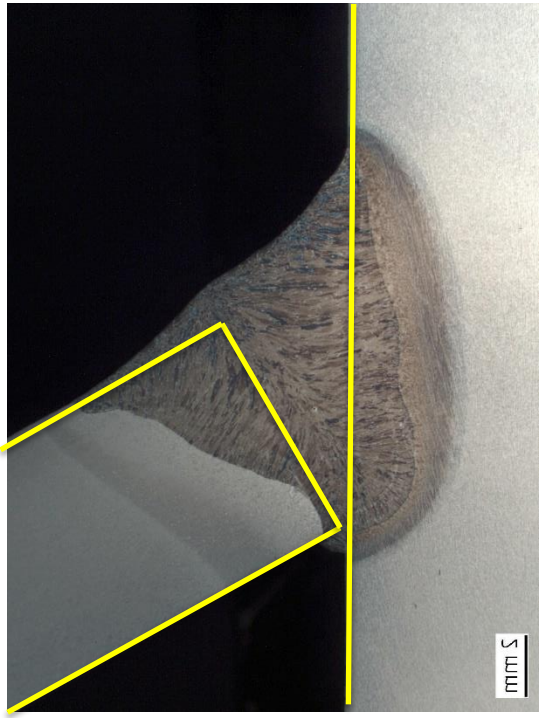
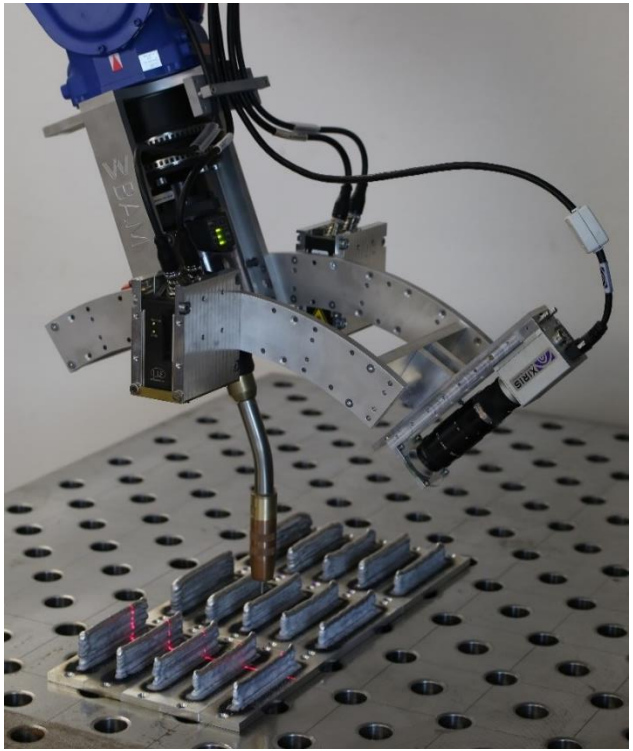


GMAW principle



weld seam cross section

introduction
Gas Metal Arc Welding (GMAW)



motivation

- promote use of Open Science and adoption of FAIR principles
  *FAIR - **F**indable, **A**ccessible, **I**nteroperable, **R**eusable*
- promote sharing and publication of welding knowledge as research data
- promote integration of existing community standards into research work

➡ **domain specific file format**

Recommendations for an Open Science approach to welding process research data.
Fabry, C. et al. Weld World (2021). https://doi.org/10.1007/s40194-021-01151-x

goals & aims

- store experimental welding data
- provide file format and open source software
- **suitable for daily research work and archival use**
- develop consistent analysis and visualization tools
- focus on implementation of arc and laser beam welding

➡ **collaborate as a welding research data community**

Recommendations for an Open Science approach to welding process research data.
Fabry, C. et al. Weld World (2021). https://doi.org/10.1007/s40194-021-01151-x

weldx core elements
“what is weldx ?”

1. weldx format
2. weldx standard
3. weldx Python API for welding + tools

weldx core elements
key features

- consistent unit support

- support for time varying data
  - as discrete data
  - as analytical expressions

- complex spatiotemporal data
  - sensors and measurements moving though space and time

- describing measurement chains

welding data exchange format
file format – basic

- The weldx format is an extension to the **Advanced Scientific Data Format** (ASDF)
  - https://github.com/asdf-format/asdf
  - https://doi.org/10.1016/j.ascom.2015.06.004

- combination of **YAML header + binary blocks** in one file

- ASDF is an extended YAML implementation for **JSON schema**

- additional features, including:
  - schema versioning
  - (circular) references
  - custom validators

welding data exchange format file format

weldx file

- store experiment information
- metadata
- experimental setup
- (raw) measurement data
- hybrid text / binary format

➡ **single file**
➡ **storage and research use**
➡ **data exchange**

schema definition files

- multiple different files
- simple text format (YAML)
- describe structure and contents
  - individual elements
  - whole weldx file
- used for validation of weldx files
- curated by individuals or community

➡ **ensure file integrity and structure**
➡ **define community standards**

welding data exchange format file format – layout

File-Header

```
#ASDF 1.0.0
#ASDF_STANDARD 1.5.0
%YAML 1.1
%TAG ! tag:stsci.edu:asdf/
%TAG !weldx! asdf://weldx.bam.de/weldx/tags/
--- !core/asdf-1.1.0
```

File-Metadata

```
asdf_library: !core/software-1.0.0 {author: The ASDF Developers,
  homepage: 'http://github.com/asdf-format/asdf', name: asdf, version: 2.8.3}
history:
  extensions:
  - !core/extension_metadata-1.0.0
    extension_class: asdf.extension.BuiltinExtension
    software: !core/software-1.0.0 {name: asdf, version: 2.8.3}
  - !core/extension_metadata-1.0.0
    extension_class: weldx.asdf.extension.WeldxExtension
    extension_uri: asdf://weldx.bam.de/weldx/extensions/weldx-0.1.1
    software: !core/software-1.0.0 {name: weldx, version: 0.6.0}
```

File-Contents

```
current: !weldx!units/quantity-0.1.0
  value: !core/ndarray-1.0.0
    source: 0
    datatype: int64
    byteorder: little
    shape: [2000]
  units: !weldx!units/units-0.1.0 milliampere
```

welding data exchange format file format – example

weldx file

```
gas_component_1: !weldx!aws/process/gas_component-0.1.0
  gas_chemical_name: argon
  gas_percentage: !weldx!units/quantity-0.1.0
    value: 82
    unit: !weldx!units/units-0.1.0 percent
```

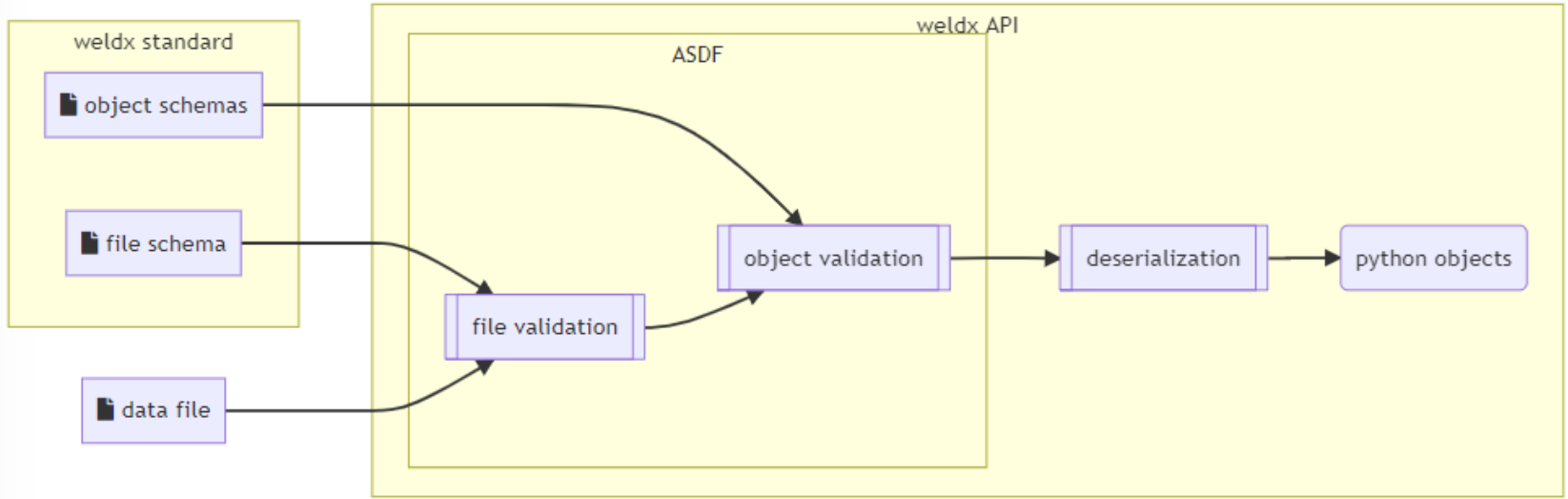
schema definition file

```
id: "weldx/schemas/aws/process/gas_component-0.1.0"
type: object
properties:
  gas_chemical_name:
    type: string
    enum:
      - argon
      - carbon dioxide
      - helium
      - hydrogen
      - oxygen
  gas_percentage:
    description: |
      Percentage by weight this gas occupies
      of the total gas mixture.
    tag: !weldx!units/quantity-0.1.0
    wx_shape: [1]
    wx_unit: percent
required: [gas_chemical_name, gas_percentage]
```

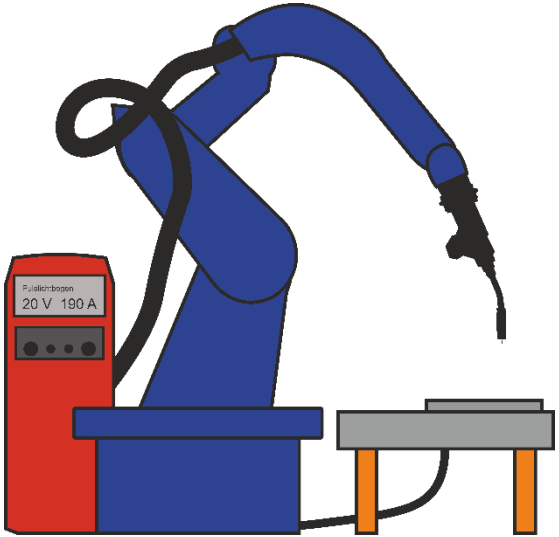
welding data exchange format file format – advanced schema example

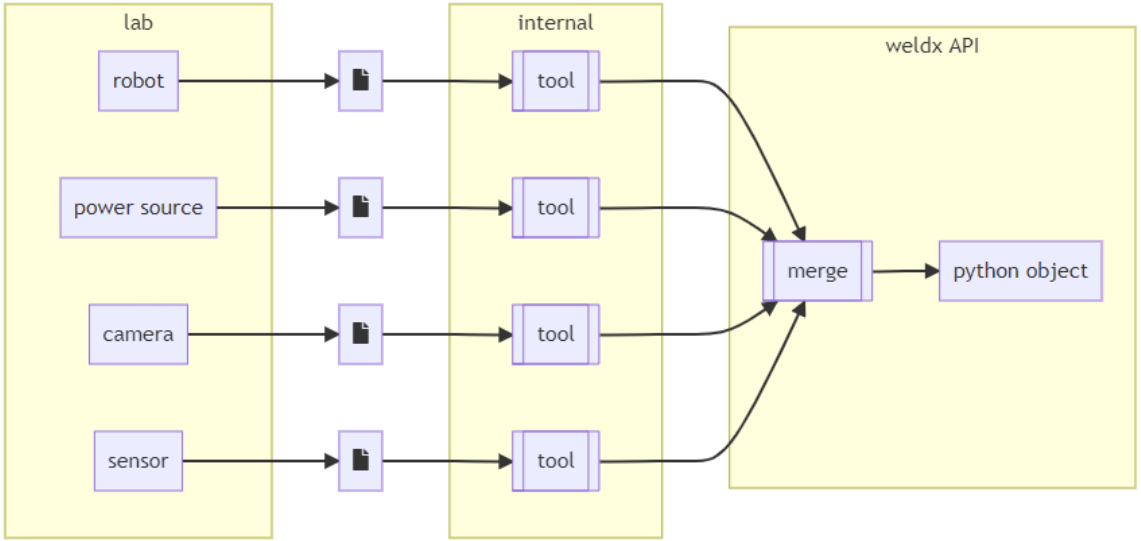
```yaml
# coordinate transformation
type: object
properties:
  coordinates:
    oneOf:
      - tag: "asdf://weldx.bam.de/weldx/tags/core/variable-0.1.*"
      - tag: "asdf://weldx.bam.de/weldx/tags/core/time_series-0.1.*"
    wx_unit: "m"
  rotation:
    tag: "asdf://weldx.bam.de/weldx/tags/core/variable-0.1.*“
  time:
    tag: "asdf://weldx.bam.de/weldx/tags/time/timedeltaindex-0.1.*"
wx_shape:
  coordinates: [..., (t), 3]
  rotation: [..., (t), 3, 3]
  time: [(t)]
```

workflows
opening and validating a weldx file

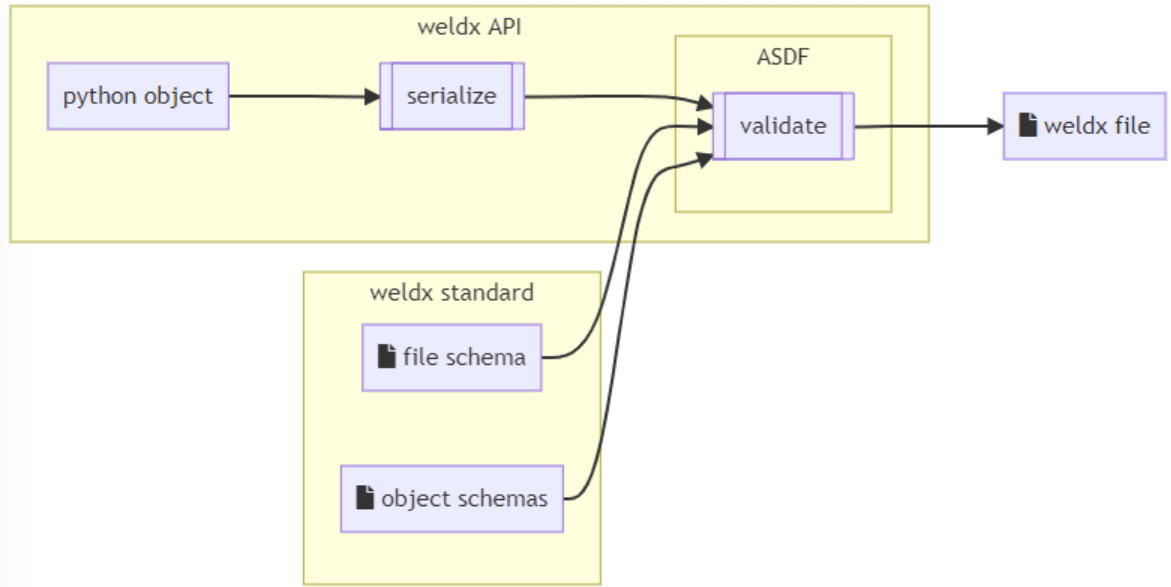


workflows
internal data processing

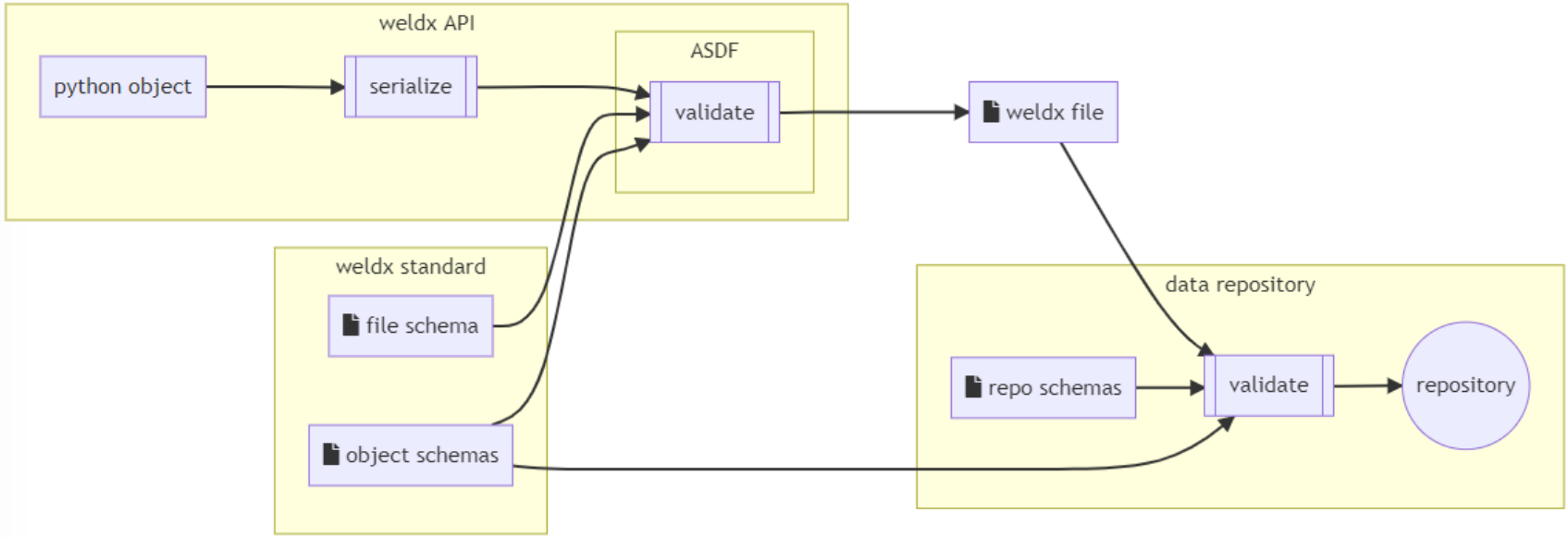




workflows
saving a weldx file



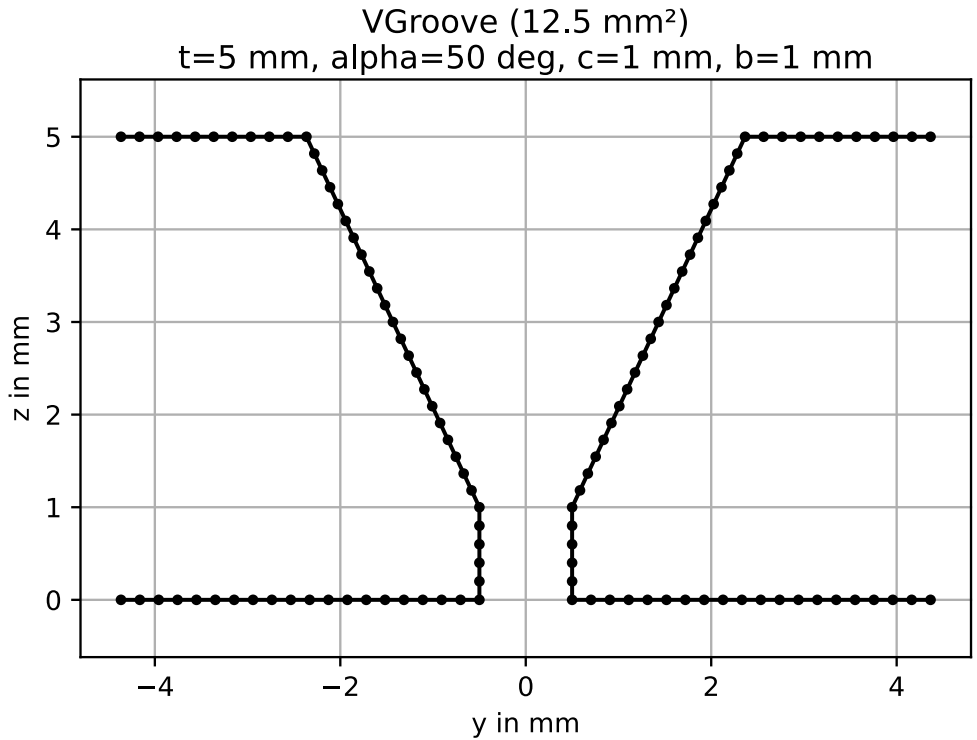
workflows
publishing a weldx file



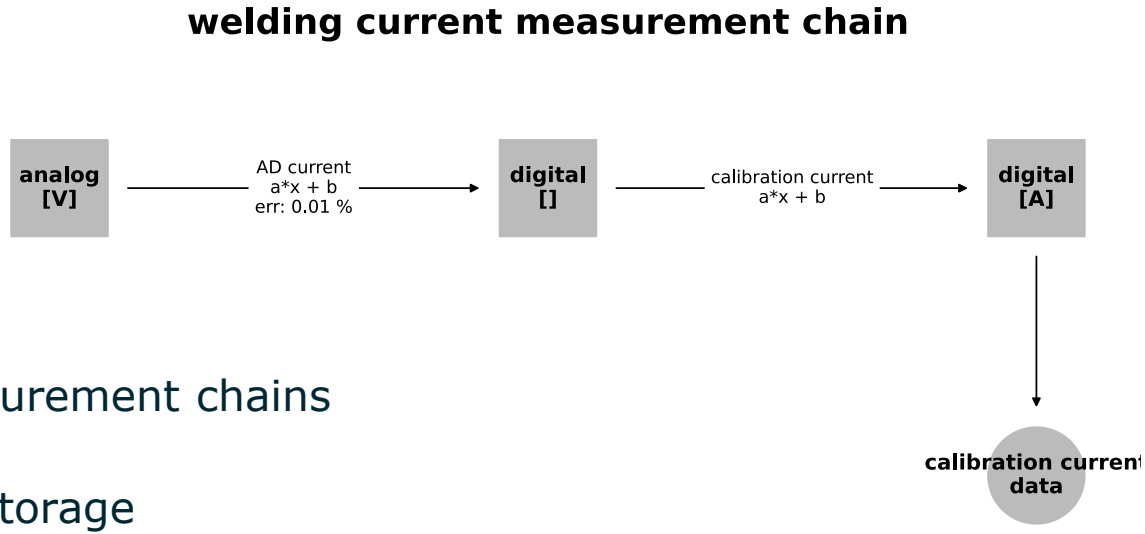
weldx API

weldx API
weldment description

- describe welding applications
- groove types
- materials & workpieces
- power source settings
- shielding gas composition



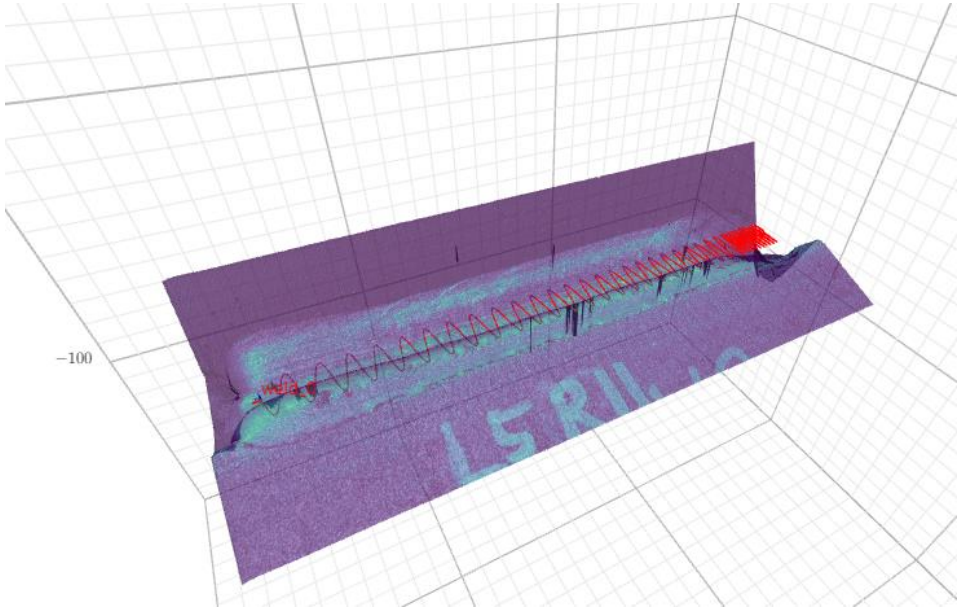
weldx API
measurement chains



- store and describe measurement chains
- signal conversions and storage
- additional metadata
  (e.g. precision, calibration certificates)

weldx API
spatiotemporal transformations

- complex welding traces
- time dependencies
- point and mesh data
- data transformation
- data interpolation



weldx API
adding external data

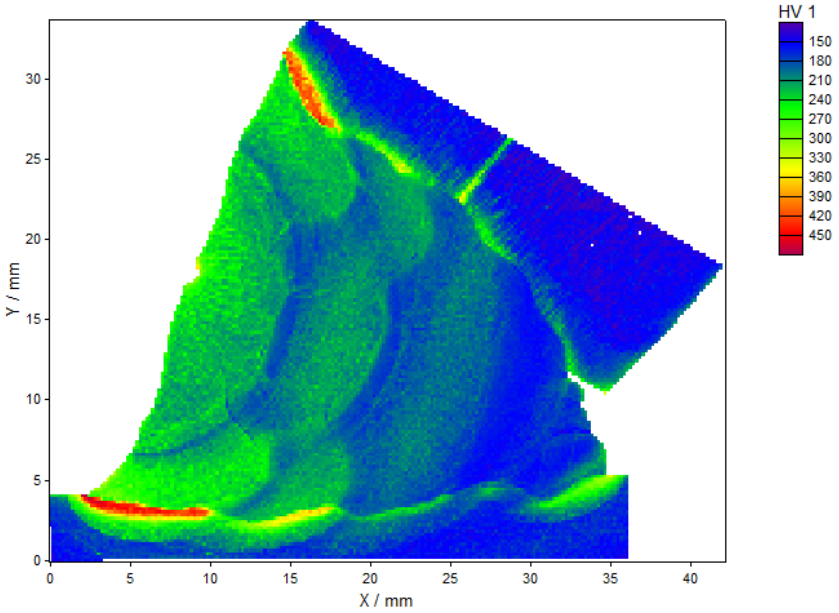
- integrate external data

- example:
  hardness measurement

weldx API
adding external data

- integrate external data

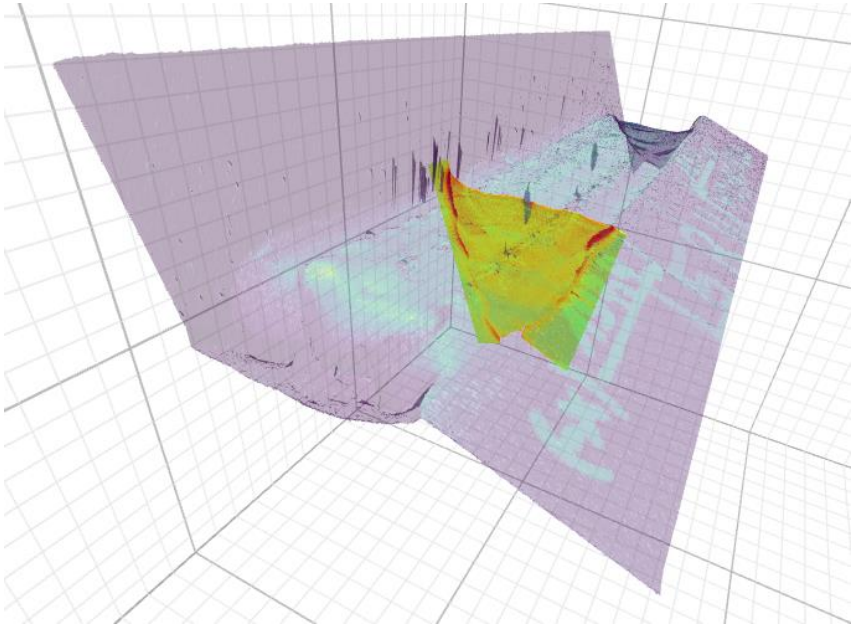
- example:
  hardness measurement



weldx API
adding external data

- add data from external sources
- example:
  hardness measurement
- read data with custom tools
- add and process data with weldx tools

➡ one file for the experiment



weldx quality standards

- weldx standard defines base elements
- user can define their own additional requirements that override the default standard
- weldx can also be extended via ASDF extensions

- Examples:
  - define a strict experimental subset (e.g. only static power source settings)
  - enforce data structures (e.g. specific shape restrictions on data or units)
  - add requirements to specific objects (e.g. every sensor must have a PDF calibration certificate)

acknowledgement

Thank you for your attention

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Questions

- **What kind of data/information is retrieved from the robot in the lab? Log files?**

- robot positioning data is collected during welding via a real time interface (EtherCAT / TwinCAT)

Questions

- **Do the files need the explicit schema markup, or can it be inferred from the key names?**

- The implementation currently uses only explicit markup.
- Adding (simple) inference should be easy (e.g. DOI)
- Where (digital) standards/onthologies etc. already exist those could be automatically translated or dynamically parsed into weldx

Questions

- **(Not coming from welding background) how WelDX is different than any other format like simple JSON?**

- Some key features compared to “simple” JSON:
  - YAML features (e.g. Anchors, Aliases)
  - binary data support (compression, slicing etc.)
  - tags to bridge into Languages/APIs
  - Schema versioning

welding data exchange format file format – advanced schema example

```
# coordinate transformation
type: object
properties:
  coordinates:
    oneOf:
      - tag: "asdf://weldx.bam.de/weldx/tags/core/variable-0.1.*"
      - tag: "asdf://weldx.bam.de/weldx/tags/core/time_series-0.1.*"
    wx_unit: "m"
  rotation:
    tag: "asdf://weldx.bam.de/weldx/tags/core/variable-0.1.*“
  time:
    tag: "asdf://weldx.bam.de/weldx/tags/time/timedeltaindex-0.1.*"
wx_shape:
  coordinates: [..., (t), 3]
  rotation: [..., (t), 3, 3]
  time: [(t)]
```

Questions

- **It looks like you're using xarray for the Python backend, is that the case?**

- Yes!
- Core numeric python stack:
  - numpy
  - xarray
  - pint + pint-xarray
  - Dask (evaluation)

- others
  - networkx
  - scipy / sympy

Questions

- **Is the usability of weldx files without API/Python an issue? -> Python is not for everybody …**

- Maybe.
- Our current idea is to have the initial (fast) core development in Python.
  Also provide faster initial benefit.
- Implementations in other languages are possible, personally I think writing “well defined” exporters to other formats is probably easier.

Questions

- **Is the weldx format already in use at other institutions?**

- Not yet, we are currently focussing on finishing up the first stable release and publishing more examples, tutorials etc.
- The idea is to start an initial series of workshops (online).