

Task 4.3 – Defect-free metal additive manufacturing

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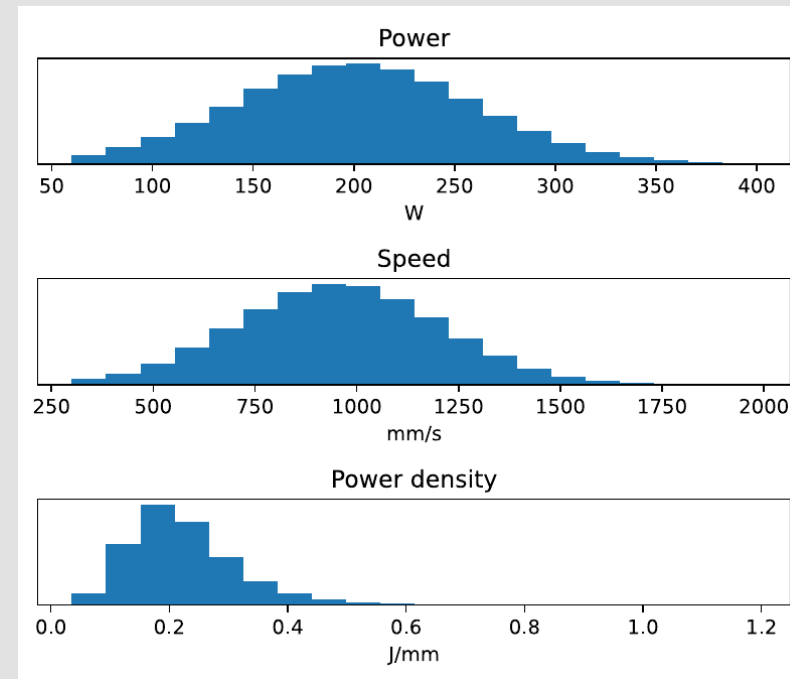
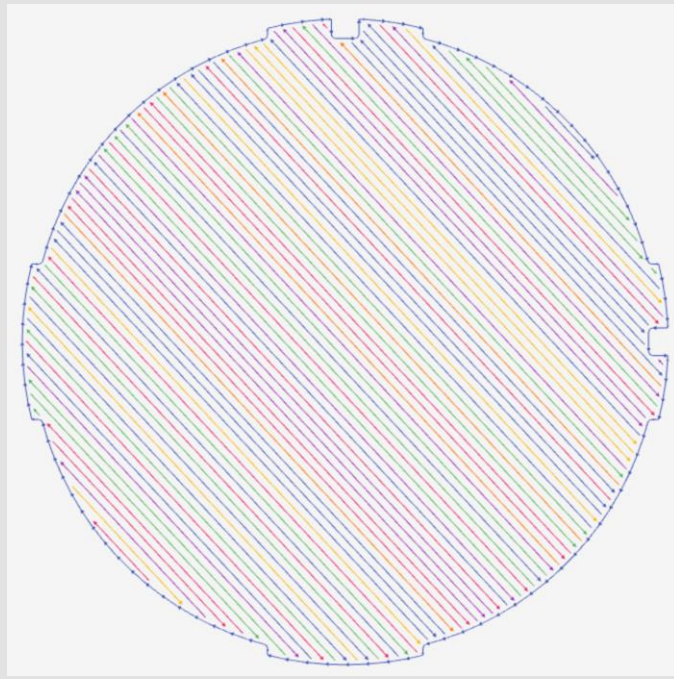
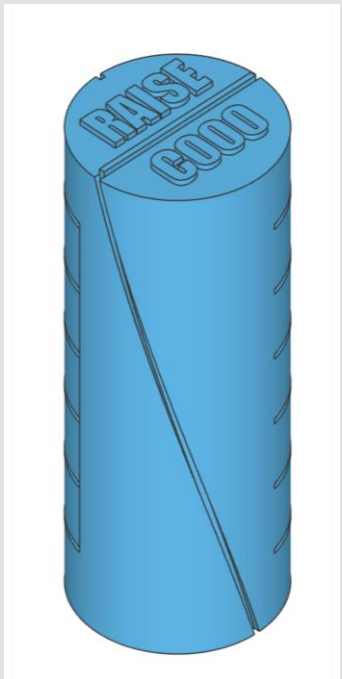
Task 4.3 – Defect-free metal additive manufacturing

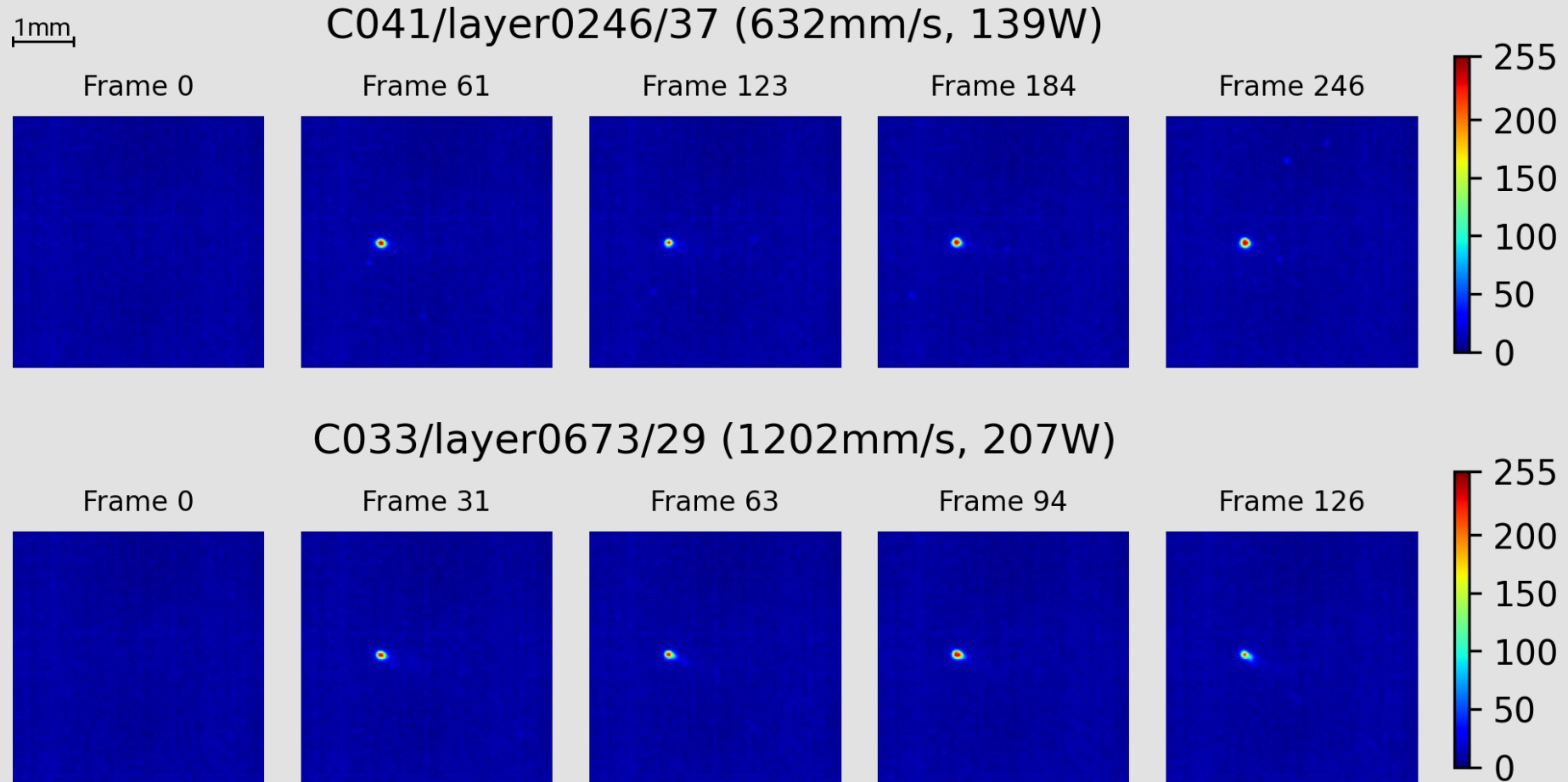
Laser powder bed fusion (LPBF) is the main industrial 3D printing process for metal parts

Major bottleneck: quality control



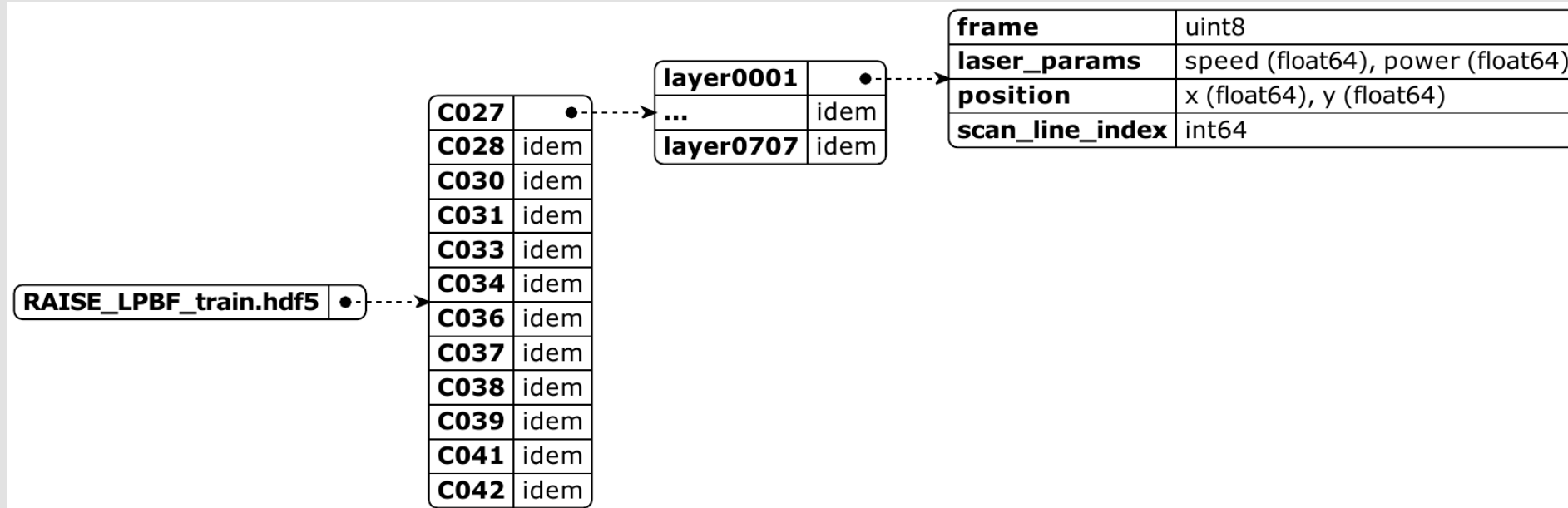
Fuse powder using randomized laser parameters





Compiled to a simple HDF5 structure

1TB



KISS principle!

Baseline models simplified as much as possible:

- Only essential preprocessing
 - No cropping
 - No camera calibration
- Default hyperparameters
- Using only a few (equidistant) frames

Results: baselines

Model	Frames used	RMSE Speed	RMSE Power	RMSE Energy density
SlowFast	32	67.6	11.1	0.0290
3D ResNet	8	157.8	19.5	0.0520
MViT	16	191.9	24.9	0.0623
Swin3D	16	205.0	25.3	0.0568

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Short Communication

Reference dataset and benchmark for reconstructing laser parameters from on-axis video in powder bed fusion of bulk stainless steel



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ARTICLE INFO

Keywords:
Selective laser melting
Stainless steel
On-axis camera
Dataset
Machine learning
Monitoring

ABSTRACT

We present RAISE-LPBF, a large dataset on the effect of laser power and laser dot speed in powder bed fusion (LPBF) of 316L stainless steel bulk material, monitored by on-axis 20k FPS video. Both process parameters are independently sampled for each scan line from a continuous distribution, so interactions of different parameter choices can be investigated. The data can be used to derive statistical properties of LPBF, as well as to build anomaly detectors. We provide example source code for loading the data, baseline machine learning models and results, and a public benchmark to evaluate predictive models.

1. Introduction

Powder Bed Fusion (PBF) is the most common Additive Manufacturing (AM) method where the powder of the chosen material (e.g., nylon, or various types of metal powder) is heated to construct the product. In laser powder bed fusion (LPBF), heat sources are laser beam (LPBF, sometimes written as laser powder bed fusion), which may re-

solution, the monitoring system observes the melt pool and monitors a set of print parameters to predict whether the current trajectory of the printing is expected to end up in generating pores. Consequently, the control unit may generate corrective control measures to prevent the generation of defects in the first place, or compensate for it by remelting the faulty region.

The very fast movements of the melting laser, i.e., laser dot speeds

Side result: AIAI conference paper



Accelerated Monitoring of Powder Bed Fusion Additive Manufacturing via High-Throughput Imaging and Low-Latency Machine Learning

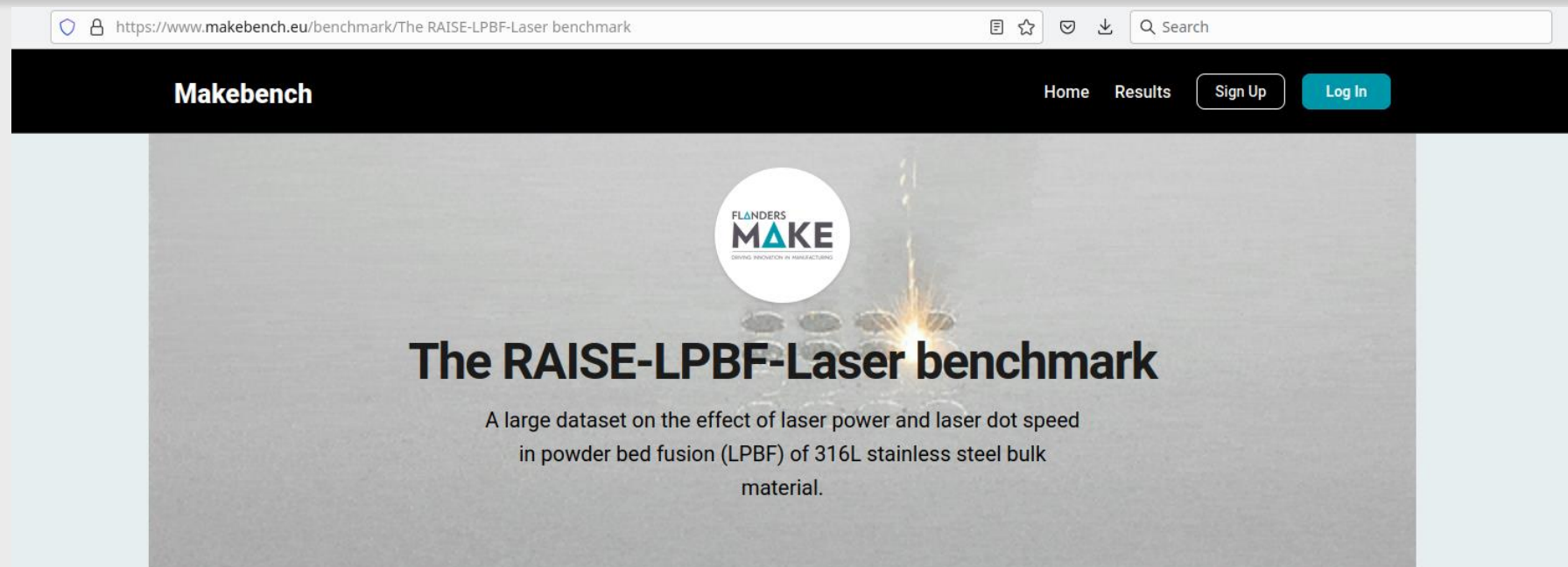
Ayyoub Ahar^(✉), Rob Heylen, Dries Verhees, Cyril Blanc, and Abdellatif Bey-Temsamani
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Abstract. Metal 3D printing in particular laser powder bed fusion is in the forefront of product manufacturing with complex geometries. However, these printed products are susceptible to several printing defects mainly due to complexities of utilizing high-power, ultra-fast laser for melting the metal powder. Accurate defect prediction methods to monitor the printing process are of high demand. More critically, such solutions must maintain a very low computational cost to enable feedback control signals for future low-latency laser parameter correction loops, preventing creation of defects in the first place. In this research, first we design an experiment to explore impact of several laser settings on creation of the most common defect called “keyhole porosity”. We print an object while recording the laser meltpool with an externally installed high-speed visual camera. After extracting keyhole pore densities, we annotate the meltpool recordings and use it to evaluate performance of a simple but fast CNN model as a low-latency defect detector.

Keywords: pore density · melt-pool monitoring · keyhole pores · defect detection · additive manufacturing · laser powder bed fusion

1 Introduction

Layer by layer 3D printing of objects with high-complex geometries has been possible in a process called Additive Manufacturing (AM) [12]. Its advantages over other traditional manufacturing methods among others are: on-demand production of uniquely designed objects in limited quantities, substantial cost reduction via shorter supply chain and less storage [3], reduced parts counts, faster and less complicated assembling and decreased time and complexity for manufacturing [10]. Various printing materials like polymers and metals (LPBF). Various printing materials like polymers and metals (LPBF).



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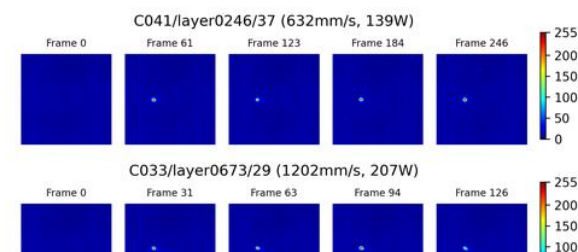
The RAISE-LPBF-Laser benchmark

A large dataset on the effect of laser power and laser dot speed in powder bed fusion (LPBF) of 316L stainless steel bulk material.

Predict laser properties

What is RAISE-LPBF-Laser?

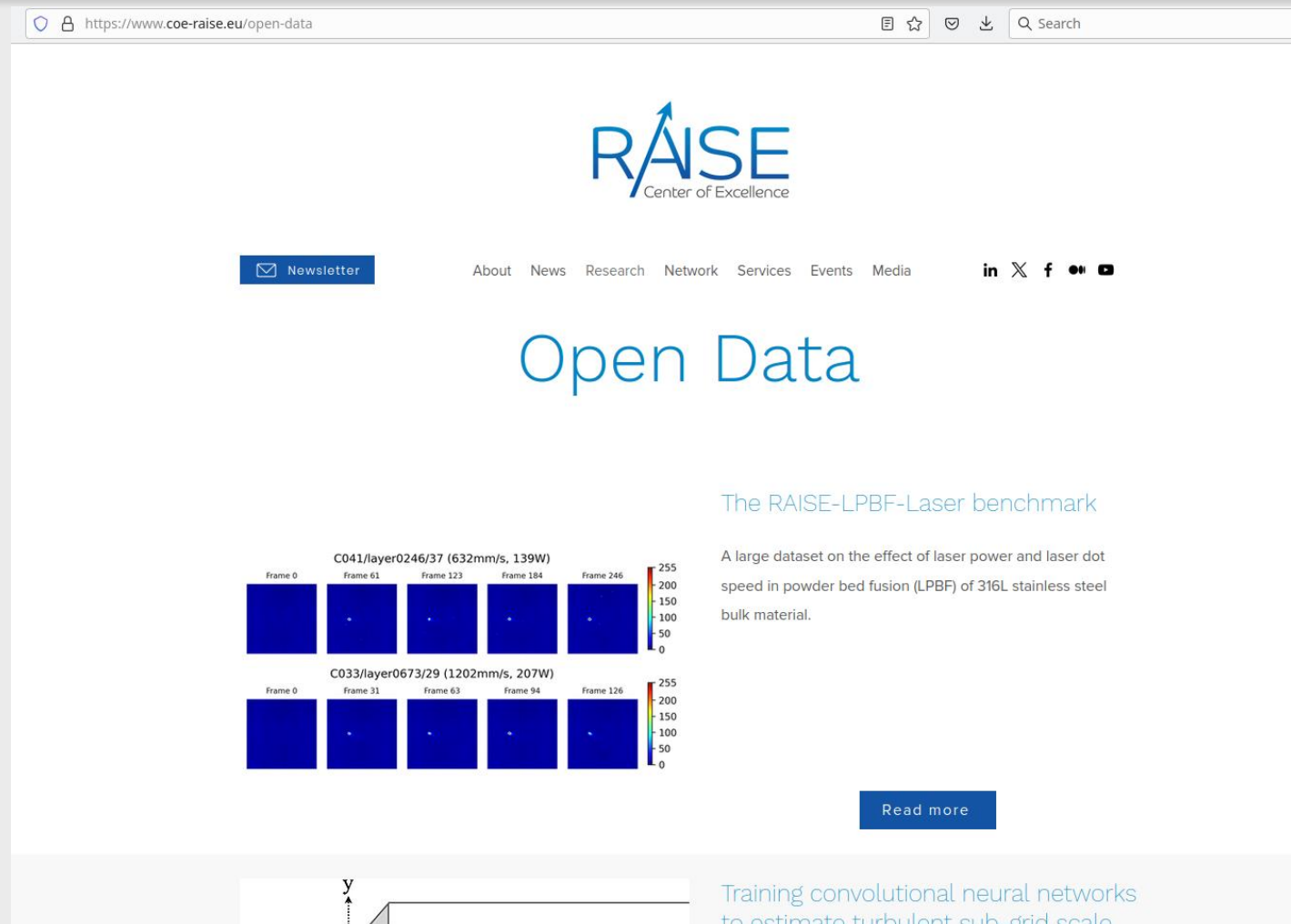
RAISE-LPBF is a large dataset on the effect of laser power and laser dot speed in 316L stainless steel bulk material. Both process parameters are independently sampled for each scan line from a continuous distribution, so interactions of different parameter choices can be investigated. The process is monitored by an on-axis camera at 20,000 frames per second. The data can be used to derive statistical properties of LPBF, as well as to build anomaly detectors. RAISE-LPBF-Laser is the machine learning benchmark to reconstruct the laser parameters of the RAISE-LPBF dataset.



Results: makebench.eu (ctd.)

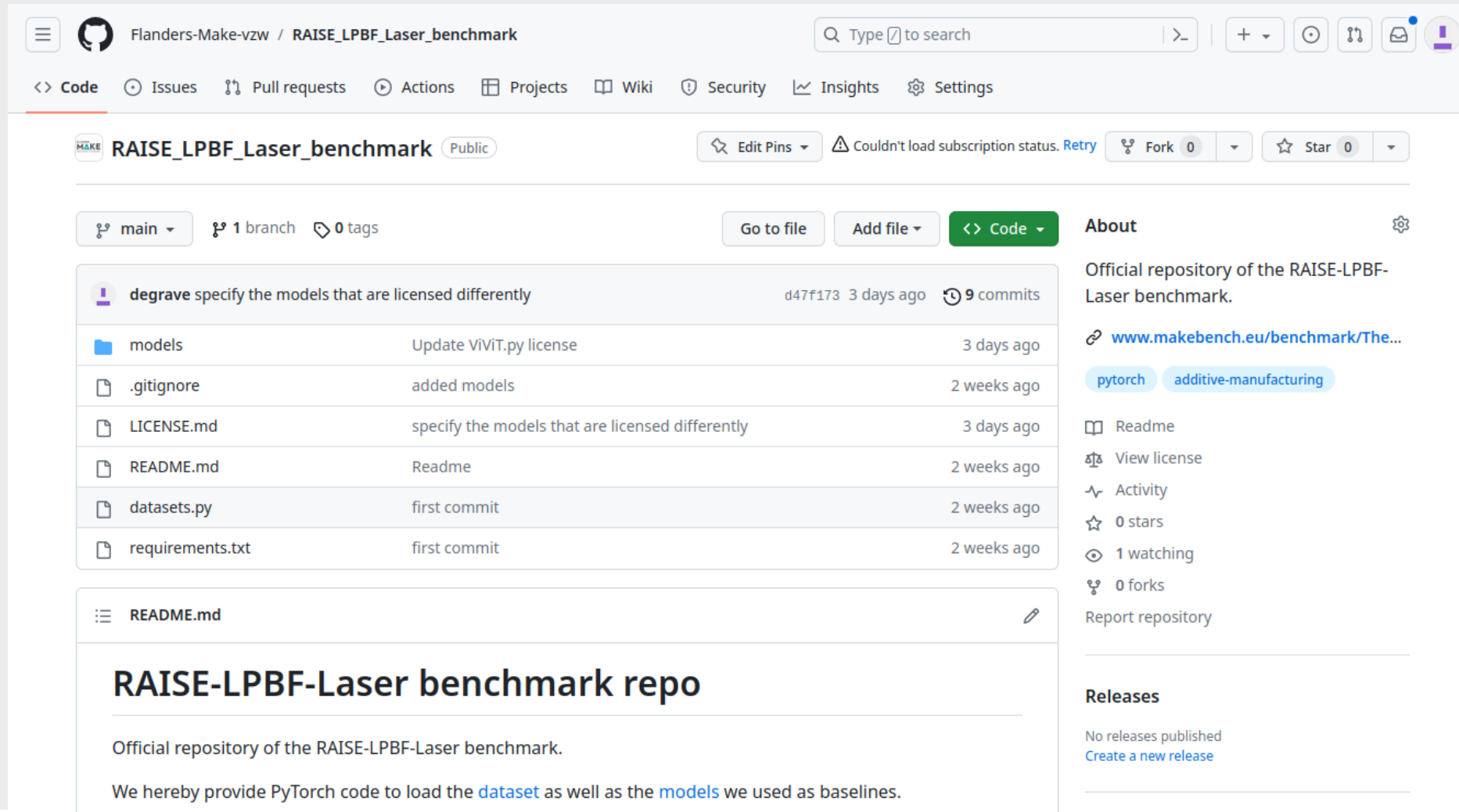
The screenshot shows the Makebench website interface. At the top, there is a black navigation bar with the text "Makebench" on the left, and "Home", "Results", "Sign Up", and "Log In" on the right. Below the navigation bar, the main content area is divided into six white cards with rounded corners, arranged in a 3x2 grid. Each card has an icon, a title, and a short paragraph of text.

- Download dataset**: Icon of a download arrow. Text: "The training data comprises 12 cylinders, the test set 4. Each cylinder has 669 fully randomized layers, each with about 84 scan lines. To each line corresponds a pair of laser parameters: speed in *mm/s* and power in *W*."
- See results**: Icon of a list menu. Text: "Check out the results and leaderboard for this dataset."
- Example code**: Icon of GitHub. Text: "Example code to load the data in PyTorch, and a few baseline AI models."
- How to submit**: Icon of a paper airplane. Text: "After you have built a predictive model on the training set, you can submit predictions for the test set to get listed on the leaderboard. Instructions on how to submit your model's predictions. (Requires login/signup.)"
- The paper**: Icon of a document. Text: "C. Blanc, A. Ahar, and K. De Grave. 'Reference dataset and benchmark for reconstructing laser parameters from on-axis video in powder bed fusion of bulk stainless steel.' Additive Manufacturing Letters (2023): 100161."
- Acknowledgements**: Icon of the European Union flag. Text: "The CoE RAISE project has received funding from the European Union's Horizon 2020 – Research and Innovation Framework Programme H2020-INFRAEDI-2019-1 under grant agreement no. 951733."



The screenshot shows the RAISE Center of Excellence website's 'Open Data' page. At the top, the RAISE logo is centered, with a navigation menu below it including 'About', 'News', 'Research', 'Network', 'Services', 'Events', and 'Media'. A 'Newsletter' button is on the left, and social media icons for LinkedIn, X, Facebook, and YouTube are on the right. The main heading 'Open Data' is prominently displayed. Below this, there are two sections of data visualizations. The first section is titled 'C041/layer0246/37 (632mm/s, 139W)' and shows five frames (0, 61, 123, 184, 246) with a color scale from 0 to 255. The second section is titled 'C033/layer0673/29 (1202mm/s, 207W)' and shows five frames (0, 31, 63, 94, 126) with the same color scale. To the right of these visualizations, a text block titled 'The RAISE-LPBF-Laser benchmark' describes a large dataset on the effect of laser power and laser dot speed in powder bed fusion (LPBF) of 316L stainless steel bulk material. A 'Read more' button is located below this text. At the bottom of the page, a small diagram shows a cross-section of a part with a coordinate system (x, y) and a vertical arrow pointing upwards.

Supporting public repo



The screenshot shows a GitHub repository page for 'RAISE_LPBF_Laser_benchmark' under the user 'Flanders-Make-vzw'. The repository is public and has 0 forks and 0 stars. The main branch is 'main'. The repository contains several files and folders, including 'models', '.gitignore', 'LICENSE.md', 'README.md', 'datasets.py', and 'requirements.txt'. The README.md file is expanded, showing the title 'RAISE-LPBF-Laser benchmark repo' and the description: 'Official repository of the RAISE-LPBF-Laser benchmark. We hereby provide PyTorch code to load the dataset as well as the models we used as baselines.' The right sidebar shows the 'About' section with the repository's purpose and a link to the benchmark website, along with 'Releases' and 'Activity' sections.

RAISE_LPBF_Laser_benchmark Public

main 1 branch 0 tags

Go to file Add file Code

degrave specify the models that are licensed differently d47f173 3 days ago 9 commits

File/Folder	Commit Message	Time
models	Update ViViT.py license	3 days ago
.gitignore	added models	2 weeks ago
LICENSE.md	specify the models that are licensed differently	3 days ago
README.md	Readme	2 weeks ago
datasets.py	first commit	2 weeks ago
requirements.txt	first commit	2 weeks ago

README.md

RAISE-LPBF-Laser benchmark repo

Official repository of the RAISE-LPBF-Laser benchmark.

We hereby provide PyTorch code to load the [dataset](#) as well as the [models](#) we used as baselines.

About: Official repository of the RAISE-LPBF-Laser benchmark. www.makebench.eu/benchmark/The...

Tags: [pytorch](#) [additive-manufacturing](#)

Readme View license Activity 0 stars 1 watching 0 forks Report repository

Releases: No releases published [Create a new release](#)

- Master Thesis postponed to H2 2023.
- Experimented with ClearML Agent in VSC cloud
 - Read-only git access (granted in advance)
 - Job isolation: OpenStack VM + Docker + non-privileged container
 - Various caches are necessary for performance but break isolation
 - Still GPU-accelerated
 - Data access still TBD

Next Steps

- Beating the baseline
- Helping others beat the baseline
- Bigger Transformers and other foundational models
 - However, industry prefers small models and cheap sensors
- Mass density model

drive. enable. innovate.



The CoE RAISE project has received funding from the European Union's Horizon 2020 – Research and Innovation Framework Programme H2020-INFRAEDI-2019-1 under grant agreement no. 951733

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