OPTIMISATION OF SURFACE TOPOGRAPHY CHARACTERISATION FOR METAL ADDITIVE MANUFACTURING USING COHERENCE SCANNING INTERFEROMETRY

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Motivation

- Metal AM surfaces are rough and can be challenging to measure, due to the presence of complex features, which include high slopes, step like recesses and protuberances, and local variations in reflectance
- Coherence scanning interferometry (CSI) is a non-contact measurement method that uses a broadband light source and interference to measure surface topography and object geometry, originally designed for measuring smooth surfaces
- Recent progress in the development of the CSI technique allows a significantly enhanced detection sensitivity through advanced measurement functions, such as filtering of the source spectrum, high dynamic range (HDR) lighting levels, adjustable number of camera acquisitions over each interference fringe (i.e. oversampling) and sophisticated topography reconstruction algorithms

Objectives

- Demonstrate the feasibility of using CSI for characterising metal AM surfaces
- Evaluate the effectiveness of relevant CSI measurement settings
- Provide recommendations for the optimisation of measurements on metal AM surfaces using CSI

CSI measurements of metal AM surfaces

	Surfaces	*Sq* /µm	*Sdq*
S1	LPBF Al-Si-10Mg cube, top surface	19 ± 2	0.6 ± 0.1
S2	LPBF Al-Si-10Mg cube, side surface	20 ± 3	1.0 ± 0.2
S3	LPBF Ti-6Al-4V cube, top surface	22 ± 3	1.1 ± 0.1
S4	EBPBF Ti-6Al-4V rectangular prism, top surface	34 ± 2	1.7 ± 0.2

Table 1. Surface texture parameters for the test cases. An S-filter and an L-filter were applied to remove high frequency noise and long scale waviness/form

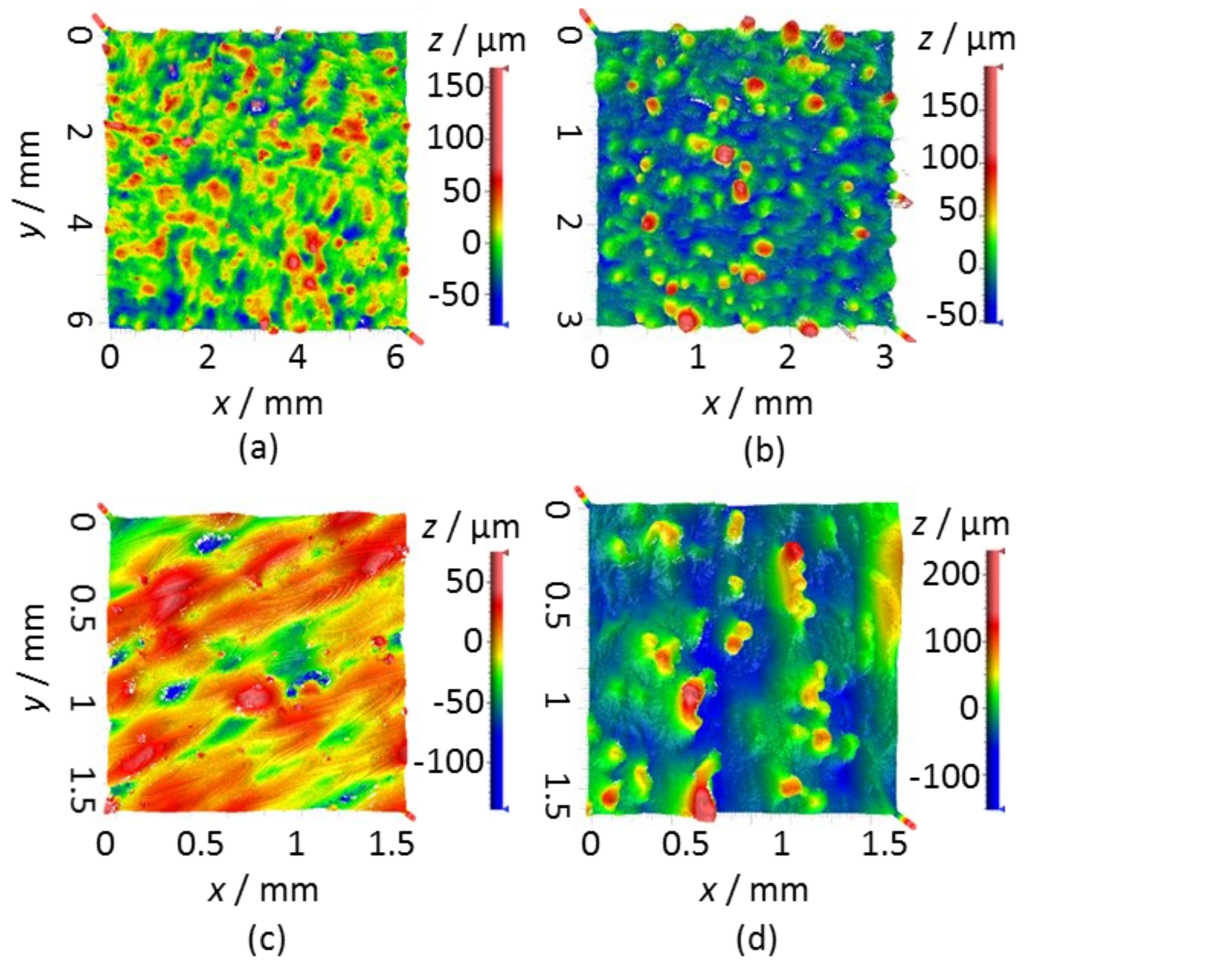

Fig. 2. CSI measurements of metal AM surfaces: (a) S1, (b) S2, (c) S3, and (d) S4. The 1.4× objective lens (1× zoom) was used for (a), the 5.5× objective lens (0.5× zoom) was used for (b), the 5.5× objective lens (1× zoom) was used for (c) and (d)

Summary and outlook

- The effects of the advanced measurement functions on the measurements of several typical AM surfaces have been demonstrated. Results show that the CSI technique is feasible for measuring surface topography in metal AM
- Increasing the signal oversampling factor in combination with the use of a narrow bandwidth source spectrum will maximise data coverage without sacrificing measurement area, but measurement time may be compromised. Recommendations are provided for the optimisation of measurements on metal AM surfaces in terms of time, measurement area and data coverage
- This study also presents insight into areas of interest for future rigorous examination, such as measurement noise and further development of guidelines for the measurement of metal AM surfaces

Method

A ZYGO NewView™ 8300 CSI system was used for this study. The experimental design covers the following aspects:

- Four common metal AM surfaces made from different materials and processes (laser powder bed fusion (LPBF), electron beam powder bed fusion (EBPBF))
- A series of measurements performed by using a combination of three objective lenses and two optical zoom factors, two spectral filters, two fringe analysis methods, five settings of signal oversampling and two HDR lighting levels. Topographic measurements are described through areal surface texture parameters *Sq* and *Sdq* and are analysed for data coverage, measurement time and area

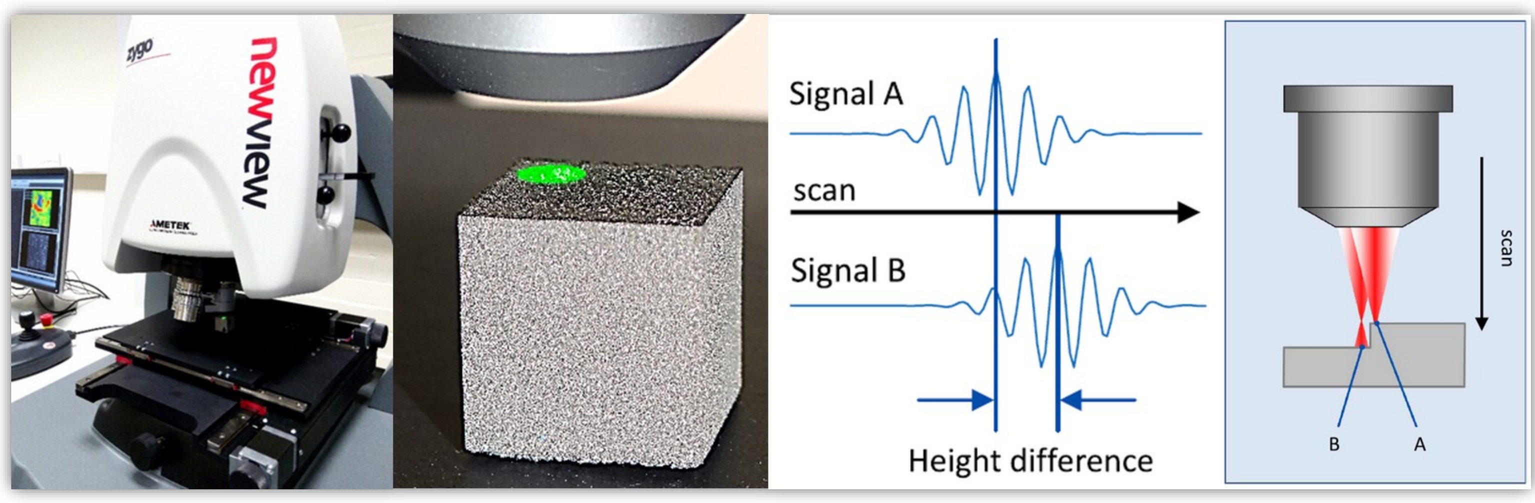

Fig. 1. CSI data acquisition (data rates are more than a million surface height points per second)

Effects of measurement functions and settings

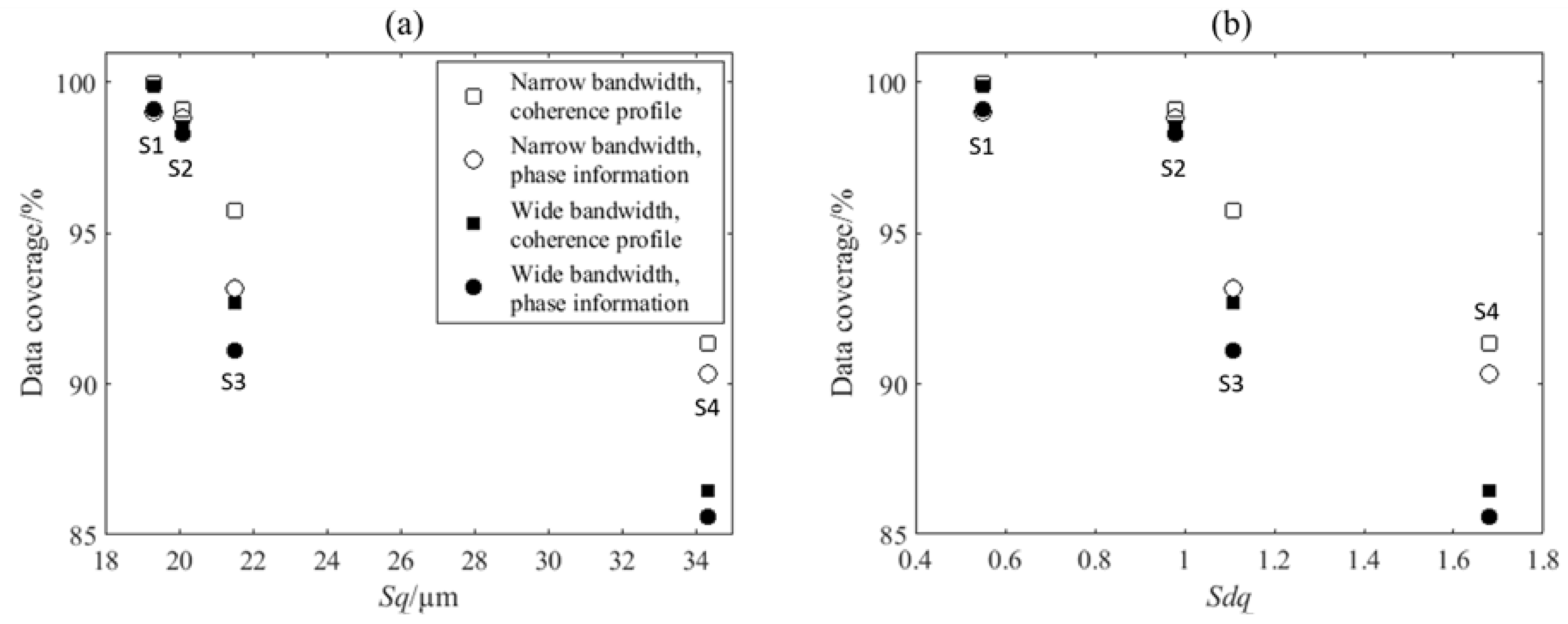

Fig. 3. Effects of spectral filtering and fringe analysis methods on data coverage. 5.5× objective lens was used. The data coverage is plotted as a function of a) Sq and b) Sdq

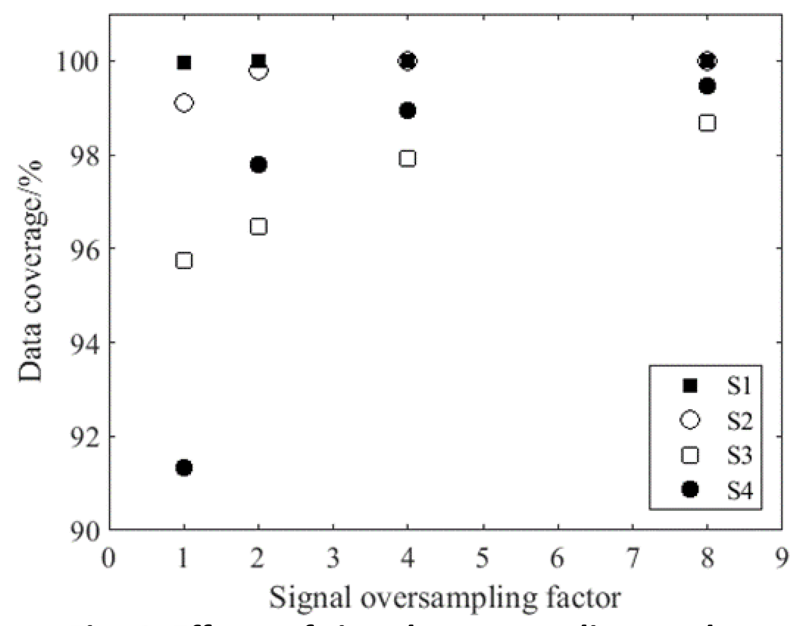

Fig. 4. Effects of signal oversampling on data coverage. 5.5× objective lens, narrow bandwidth spectrum and coherence profile fringe analysis method were used

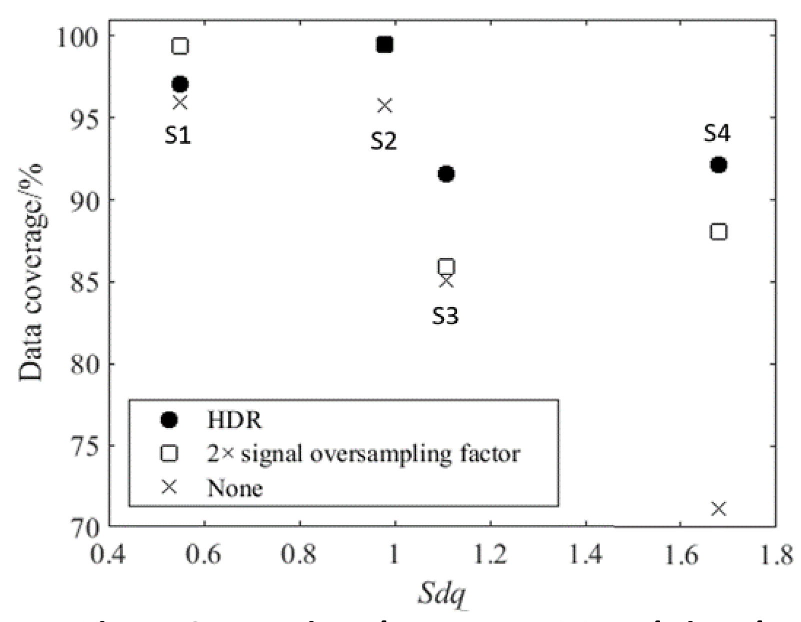

Fig. 5. Comparison between HDR and signal oversampling and a measurement performed without using advanced functions. The data coverage is plotted as a function of Sdq

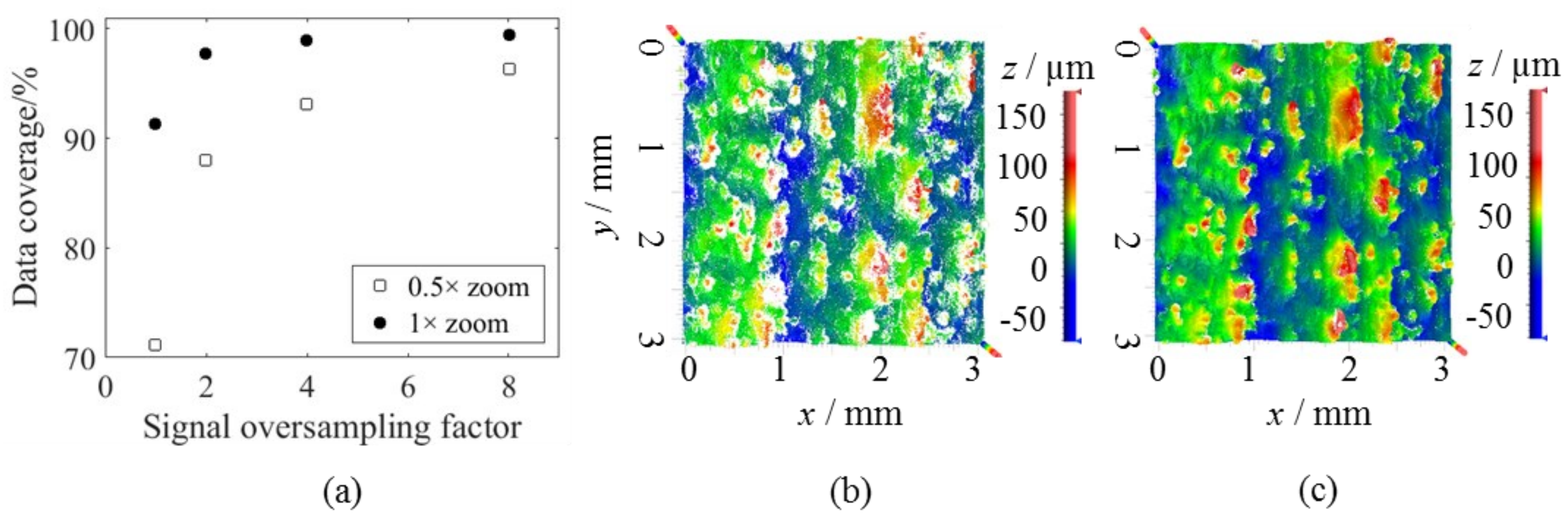

Fig. 6. Effects of signal oversampling on data coverage for S4. 5.5× objective lens, narrow bandwidth spectrum and coherence profile fringe analysis method were used. (a) Effect of camera exposure time; (b) measurement without signal oversampling (0.5× zoom); and (c) result with 8× signal oversampling (0.5× zoom)

	S1/S2	S3	S4
Source spectrum filtering		Narrow (40 nm BP filter)	
Fringe analysis method		Coherence profile	
Zoom lens		1×	
Objective lens	1.4×*	5.5×	5.5×
Oversampling factor	--	-- or 4*	2 or 8*

* For data coverage > 99 %

Table 2. Measurement optimisation for metal AM surfaces (95% data coverage by default)