

Thermographic super resolution reconstruction using 2D pseudo-random pattern illumination

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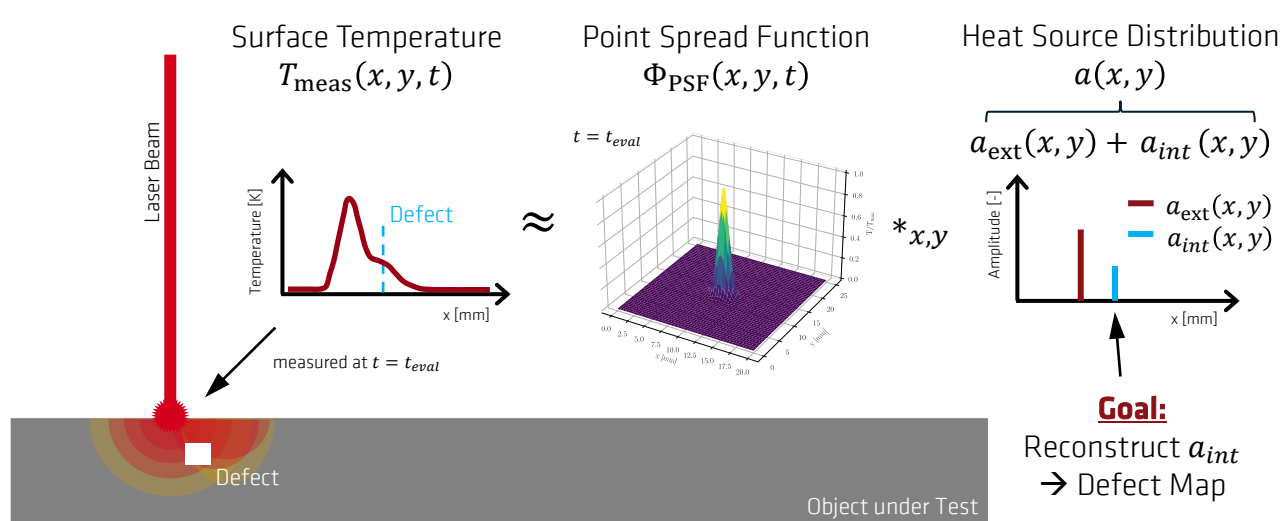


Abstract

Thermographic non-destructive testing is based on the interaction of thermal waves with inhomogeneities. The propagation of thermal waves from the heat source to the inhomogeneity and to the detection surface according to the thermal diffusion equation leads to the fact that two closely spaced defects can be incorrectly detected as one defect in the measured thermogram. In order to break this spatial resolution limit (super resolution), the combination of spatially structured heating and numerical methods of compressed sensing can be used. The improvement of the spatial resolution for defect detection

then depends in the classical sense directly on the number of measurements. Current practical implementations of this super resolution detection still suffer from long measurement times, since not only the achievable resolution depends on performing multiple measurements, but due to the use of single spot laser sources or laser arrays with low pixel count, also the scanning process itself is quite slow. With the application of most recent high-power digital micromirror device (DMD) based laser projector technology this issue can now be overcome.

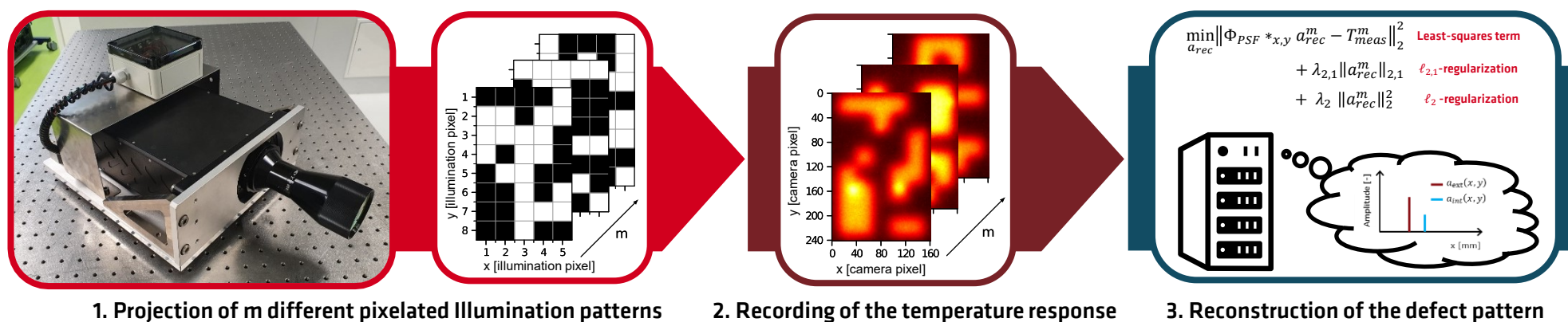
MOTIVATION: PHOTOTHERMAL SUPER RESOLUTION RECONSTRUCTION



Modelling Approach

A typical surface temperature profile for heating an object with a point source shows a small temperature peak/saddle point over a sufficiently defective region due to the impedance of the local heat flow. This distribution can be modelled in a Greens function like approach as the spatial convolution of a thermal point spread function $\Phi_{\text{PSF}}(x, y, t)$ (Kernel) and a heat source distribution term $a(x, y)$. This term contains not only the position of the external heating a_{ext} as a Dirac-like pulse but also encodes the defect response a_{int} as an additional signal. Filtering out those defect signals and combining multiple measurements allows for a complete reconstruction of the internal defect structure.

EXPERIMENTAL APPROACH

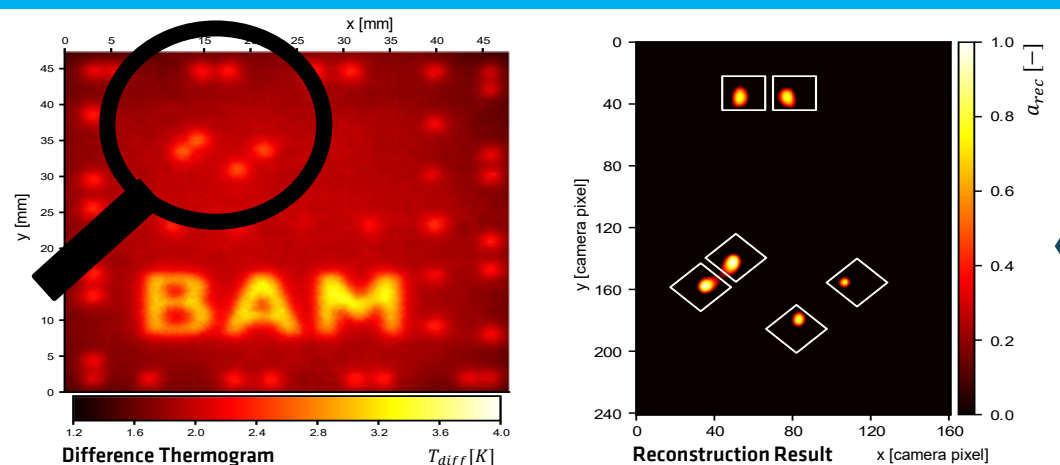


In order to achieve super resolution capabilities in comparison to conventional thermographic testing methods, multiple measurements are performed using 2D-structured pixelated illumination patterns. This can be achieved by employing a fiber-coupled high-power laser based DMD-projector which can project arbitrary pixel patterns at high optical output power. The corresponding

temperature profiles for each measurement is recorded and the resulting data is fed into a numerical reconstruction algorithm which solves the model equation for the internal heat source distribution a_{int} by exploiting the (joint-) sparsity of the defect structure between the different measurements.

RECONSTRUCTION RESULTS

If we compare the result of conventional thermographic testing method (difference thermogram; left image) with the presented photothermal super resolution reconstruction approach (right image) for a region of interest containing multiple internal defects with close spacing, it can be clearly seen that the defects can be separated by the presented reconstruction approach even at tight spacings. Furthermore, a defect map free of any background signal and noise is obtained.



Sicherheit in Technik und Chemie

Further Reading:

- [1] Lecomagnon et al., Thermographic detection of internal defects using 2D photothermal super resolution reconstruction with sequential laser heating, DOI: [10.1063/5.0088102](https://doi.org/10.1063/5.0088102)
 [2] Lecomagnon et al., Thermographic testing using 2D pseudo-random illumination and photothermal super resolution reconstruction, DOI: [10.1117/12.2618562](https://doi.org/10.1117/12.2618562)
 [3] Lecomagnon et al., Investigations on photothermal super resolution reconstruction using 2D-structured illumination patterns, DOI: [10.1117/12.2603838](https://doi.org/10.1117/12.2603838)

