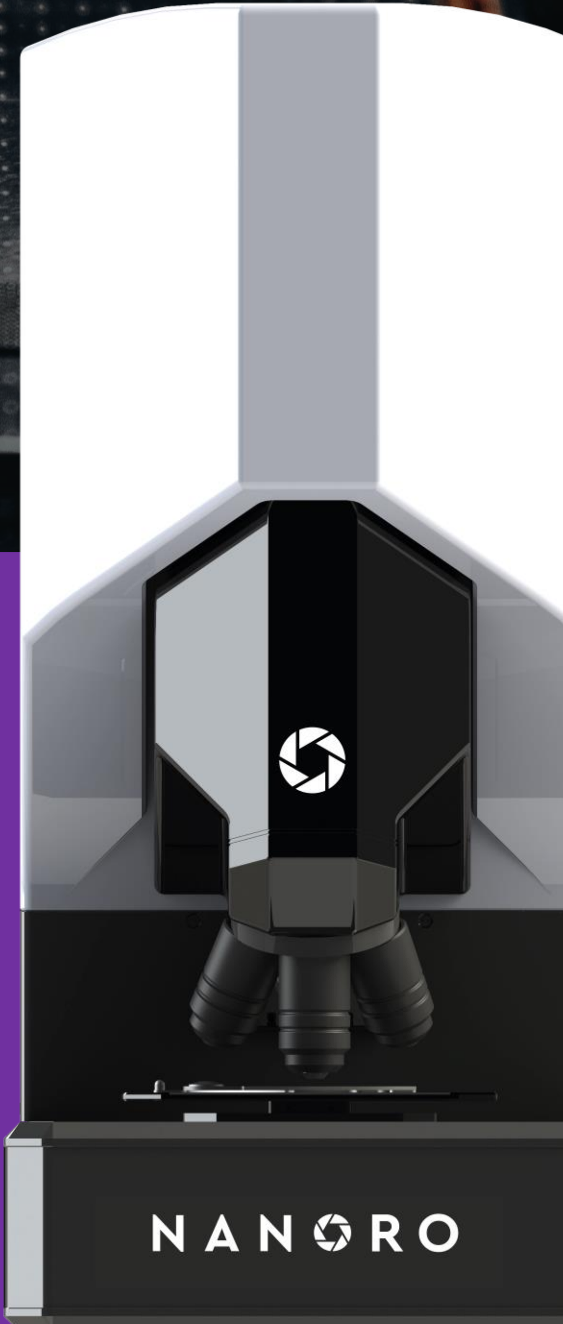
Technical Note for Super Resolution White Light DRY Imaging



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Dry Imaging down to 50 nm

Introduction:

State of the art white light imaging resolution is limited to around 200 – 250 nm due to the diffraction limit of light. To achieve this requires immersion lenses / medium as well as a perfect setup (and most setups are not perfect!). For comparison, SMAL immersion lenses can image features down to 50 nm, well beyond the diffraction limit of light.

The Problem:

The highest resolution white light optical lenses require an immersion medium and so are less suited to applications in the semiconductor and advanced materials markets where highly sensitive and costly samples will not tolerate use of solutions.

Our Solution:

LIG Nanowise have developed a new SMAL-Air lens which allows users to observe the same small features without an immersion liquid. Figure 1 below shows a snap-shot of a microprocessor that reveals the 50 nm structures imaged in the dry with our SMAL-Air lens. As proof, the following pages describe an imaging environment that is unable to support liquid water.

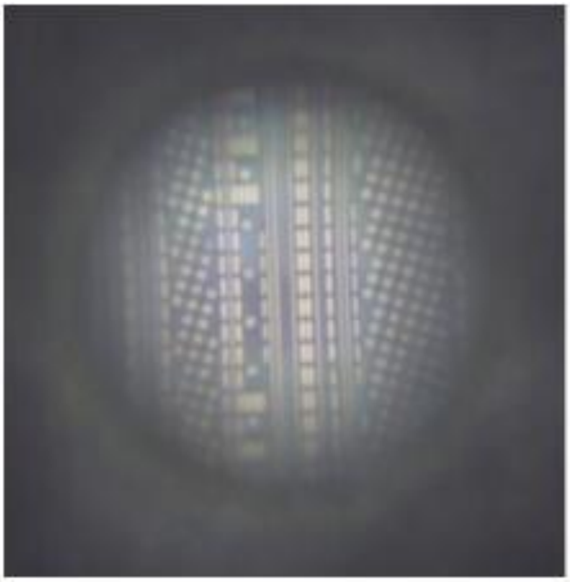

Fig.1 SMAL-Air imaging of 50 nm gap between structures.

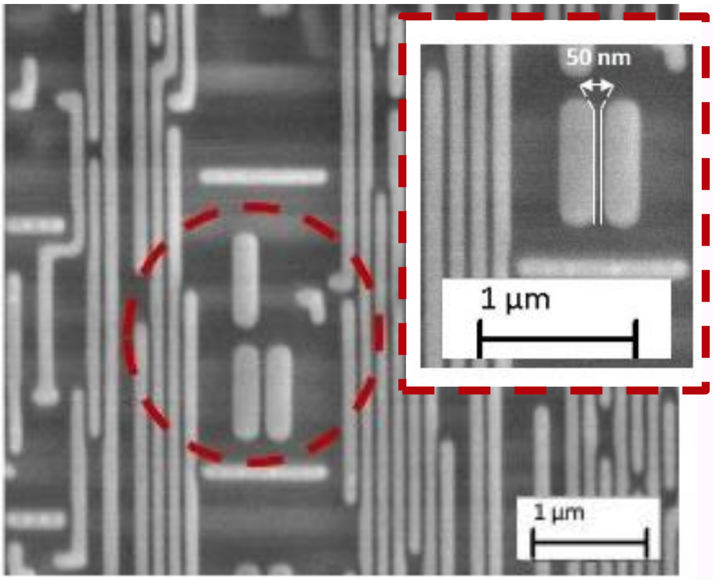

Fig.2 SEM image of the same sample measuring the 50 nm gap between features

Vacuum Imaging set-up (1/2)

To avoid water interfering with our dry-imaging, we engineered vacuum chamber with sample heater to ensure water could not exist in a liquid state. This was to prevent humidity adsorbing to and/or coalescing on both sample and lens surfaces, creating an unwanted immersion medium.

Experimental set up: A new, dry super-resolution microprocessor sample was placed on a heating plate in a Perspex vacuum chamber that allowed the SMAL-Air objective lens through to the sample's surface by way of an aperture. An externally powered linear stage was placed inside the chamber, providing fine control over the lens-sample focal point under vacuum conditions. Initial course sample positioning was provided by micrometre stages as shown (right), and initial setup was done in normal atmospheric conditions. Once the initial setup was completed, silicon was used to seal around the lens, control, measurement and heater wires that passed into the chamber and a valved vacuum port was connected with an external vacuum pump. Elements of a Nanoro-M microscope were constructed around the chamber to allow software acquisition of the images and control of the focus.

Vacuum and temperature measurement: The pressure inside the chamber is monitored by a lever gauge, while a k-type thermocouple attached to the microprocessor sample allow us to monitor the temperature. The recorded pressure inside the chamber during the imaging was 55 mbar while the temperature was 66.4 ^{o}C.

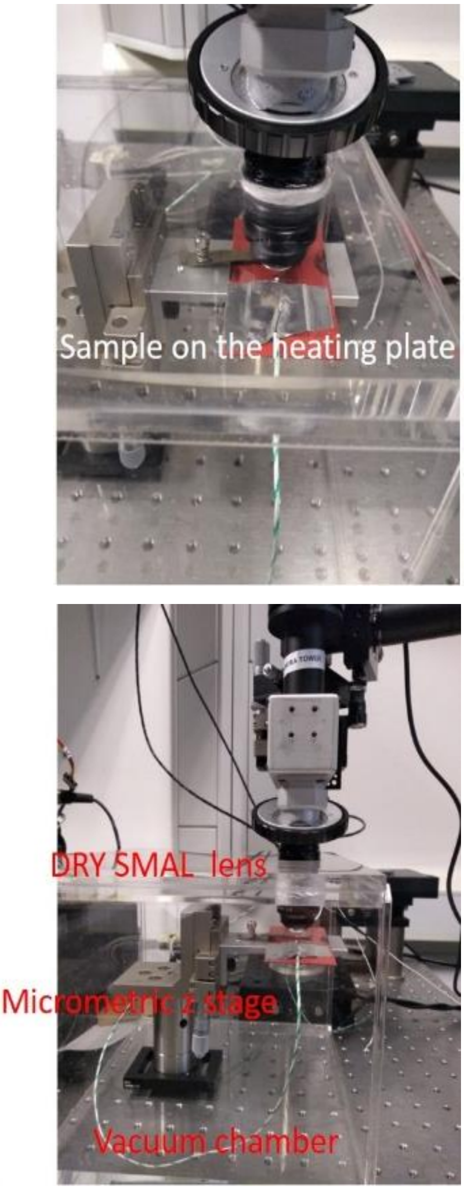

Fig.3 Vacuum chamber's experimental set-up

Vacuum Imaging set-up (2/2)

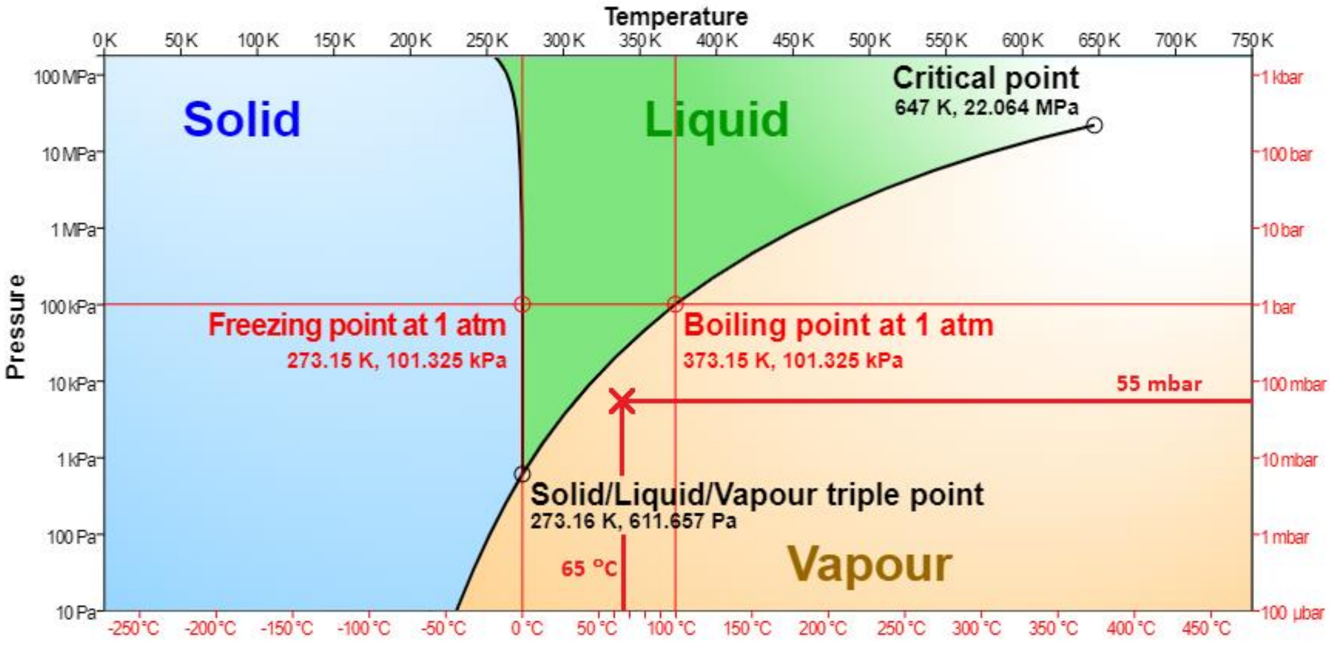

Fig.4 Phases of water versus temperature and pressure. The red cross indicates the imaging operation takes place well within the Vapour phase (65 °C / 55 mbar) where liquid water can not exist.

Pressure measurement: The pressure gauge indicated a difference in pressure of 0.96 bar between the ambient and chamber pressures. As the environmental pressure was 1.015 bar on the day of the test, we can conclude that the chamber pressure was 0.055 bar, as indicated on figure 4.

Consequently, due to the sample heating and the chamber pressure, we can be sure that no liquid water existed during the imaging, as displayed on the next page.

Imaging in a vacuum: The SMAL-Air lens was used to image the sample inside the vacuum chamber at the experimental conditions described above and the following images are the result of that work. The automatic translation stage was used to approach the sample and ensure the sample remained in focus during the experiment.

Results

Performance in the dry:

For reference, figure 5 shows comparative images obtained in both ambient atmospheric conditions (left) and under the above described conditions (right). The fine features show lines that are approximately 80 - 100 nm in width.

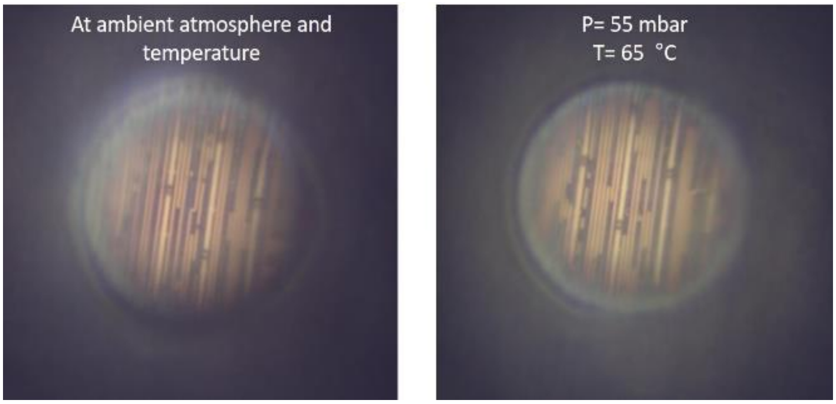

Fig.5 SMAL-Air imaging at ambient temperature and pressure (left) vs the experimental conditions (right)

SMAL-Air vs state-of-the-art 100x 0.9 NA objective lens: A second sample with features beyond the diffraction limit was imaged with both a traditional lens and a SMAL-Air lens to compare the resolving powers, as shown in figure 6. You can clearly see the improved resolving power of the SMAL-Air lens vs the 100x air lens.

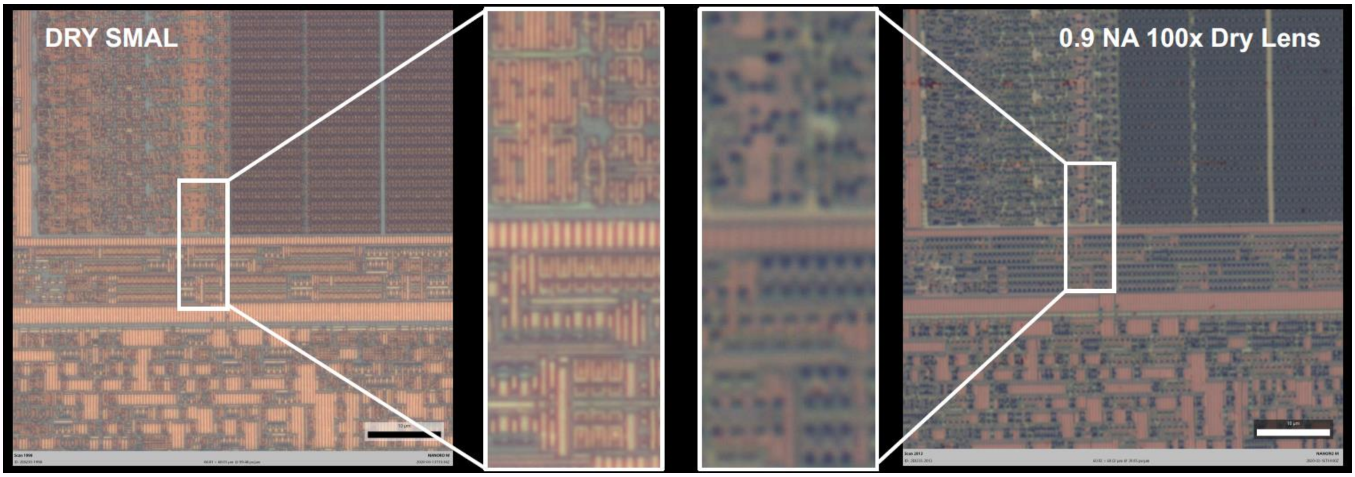

Fig 6. Comparison between SMAL-Air and state of the art (traditional) 0.9 NA 100x lens.

Conclusion: In figure 5, the ambient temperature and pressure image is near identical to the vacuum chamber image in terms of its resolution and feature content. This indicates that SMAL-Air does not rely on humidity or an immersion medium to create the same profound image quality enhancements over state-of-the-art optics, as demonstrated in figure 6. Indeed, the same level of resolution can be seen in the SMAL-Air as can be seen in the SMAL immersion lenses, something we attribute to the Super-Resolution Amplifying Lens' amazing ability to see beyond the diffraction limit.

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