Thermo-Fluids Research Centre
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Feasibility study of PLIF technique to visualize temperature field in clearances of positive displacement rotary machines

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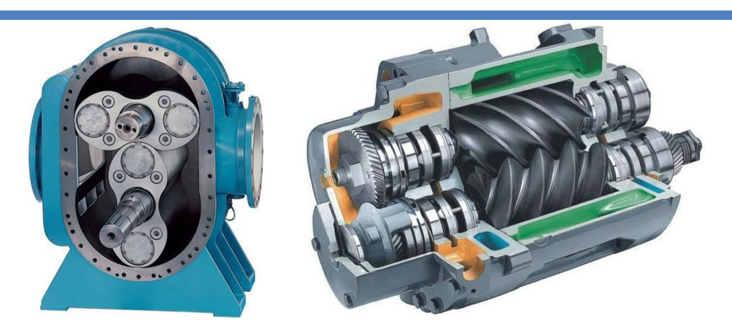
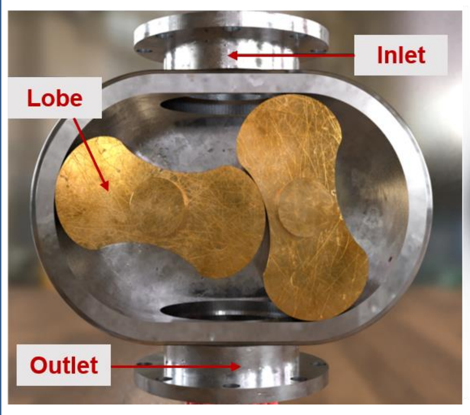
Positive displacement rotary machines are widely used in the industry. Their efficiencies are greatly influenced by the leakages through gaps between stationary and rotating parts of the machine. These clearance gaps vary in running condition because of the heat transfer between the working fluid and the machine parts, and it may result in reliability issues. In order to improve the reliability and efficiency of PDMs, it is necessary to understand the physics of heat transfer and flow dynamics in the clearance gaps.



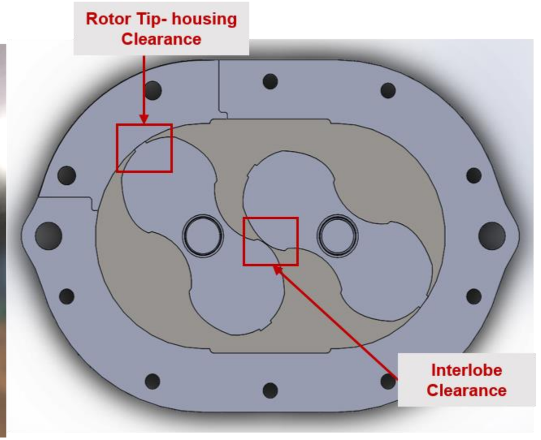
1. Why feasibility study of PLIF?

There is no established technique available which help to visualize the temperature field in micron size clearance in operating condition of rotary machines. That's why an assessment of practical use of the anisole-based **Planar Laser-Induced Fluorescence (PLIF)** carried out for leakage flow analysis to uncover its strengths and weaknesses.

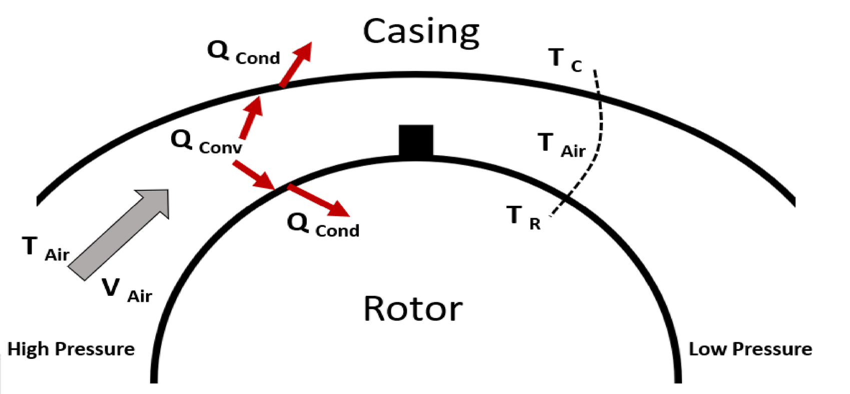
2. Heat transfer in clearances of the roots blower



Components of actual roots blower



Clearances in Roots blower



Temperature behaviour from air to rotor and casing in radial clearance of roots blower

3. Principle of PLIF imaging

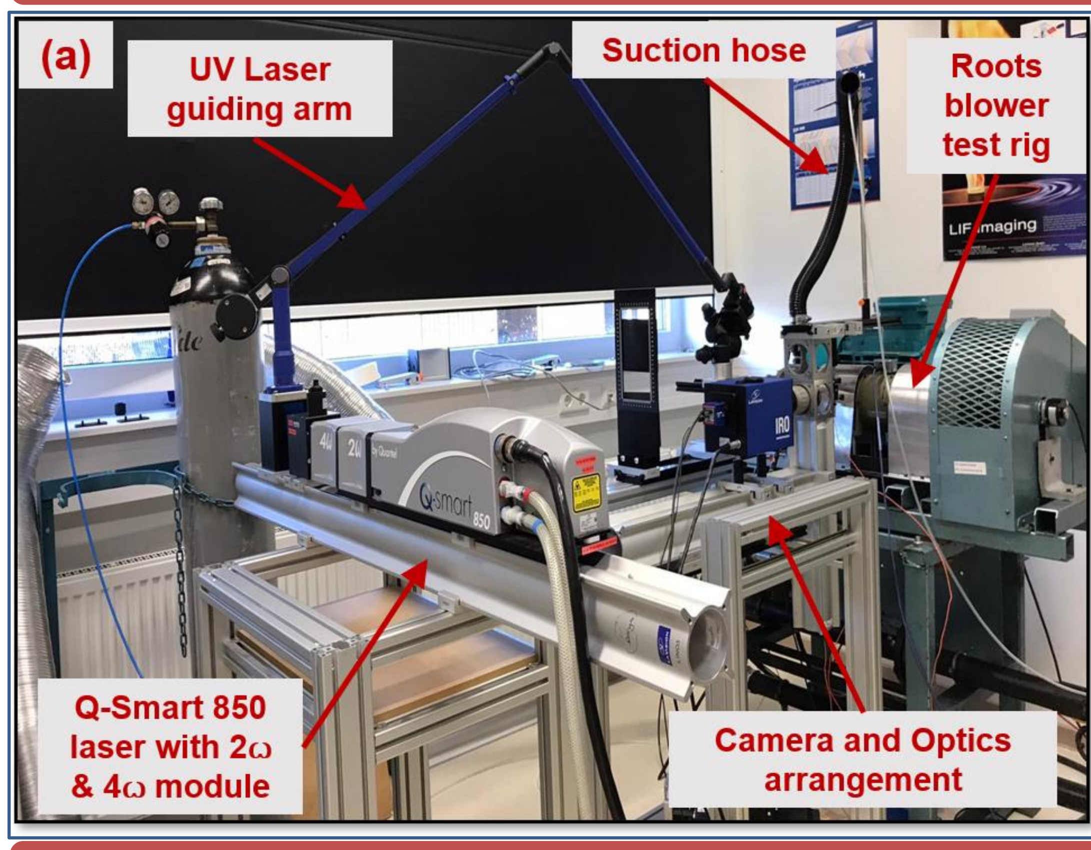
This technique works on capturing the intensity of illuminated fluorescence particles. Ratio of signal intensity captured at two different wavelengths is the function of temperature as per equation 1.

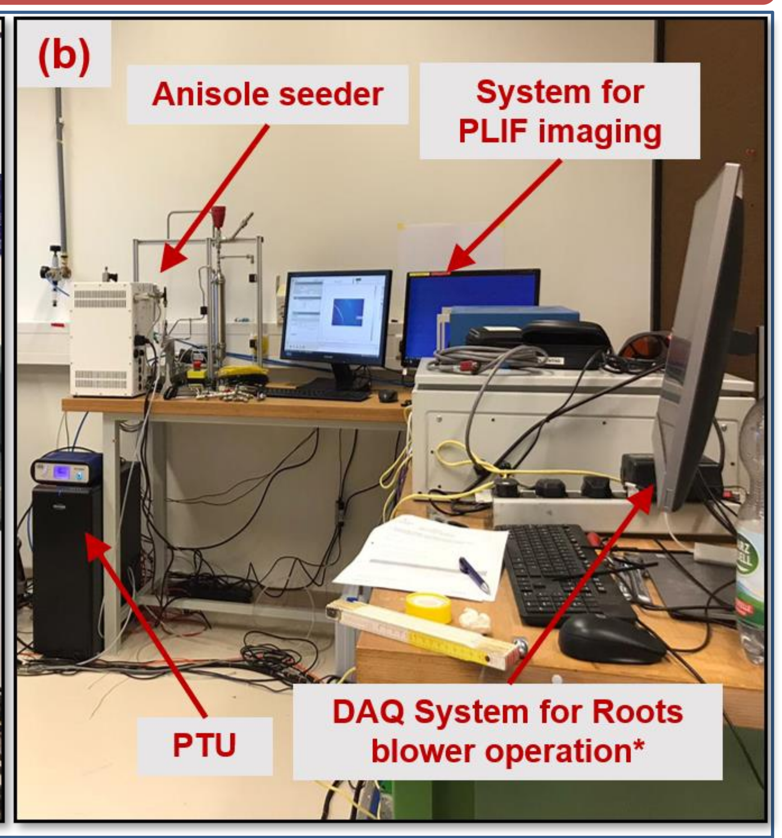
$$\frac{S_{320}}{S_{280}} = C\frac{\sigma_{abs}\varphi_{f_{320}}}{\sigma_{abs}\varphi_{f_{280}}} = f(T, v_{O_2}) \quad [1]$$

Where,

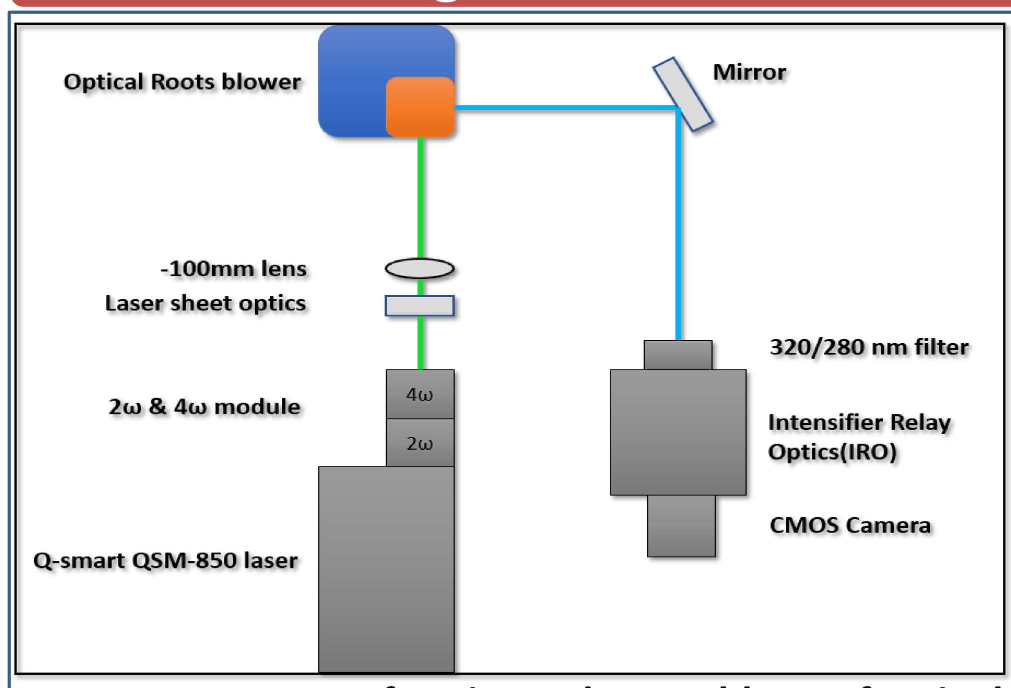
S_{320}, S_{280}	Collected LIF signal at particular wavelength
σ_{abs}	Absorption cross-section
φ_f	Fluorescence quantum yield
T	Local temperature
v_{O_2}	Local Oxygen concentration
C	Constant incorporates efficiency of the detection optics

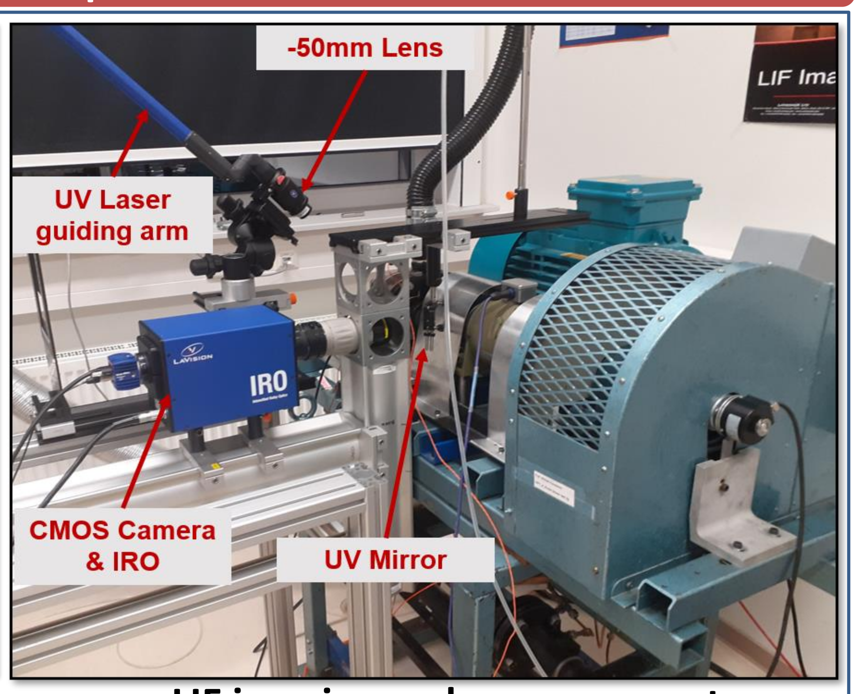
4. PLIF test setup with optics and DAQ





5. Single camera LIF test setup and results

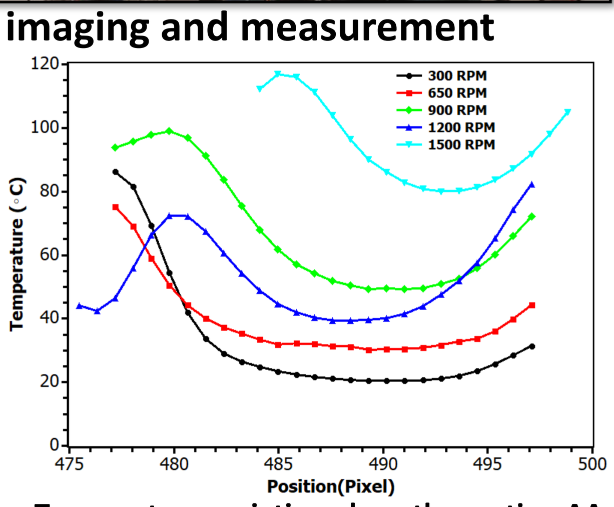




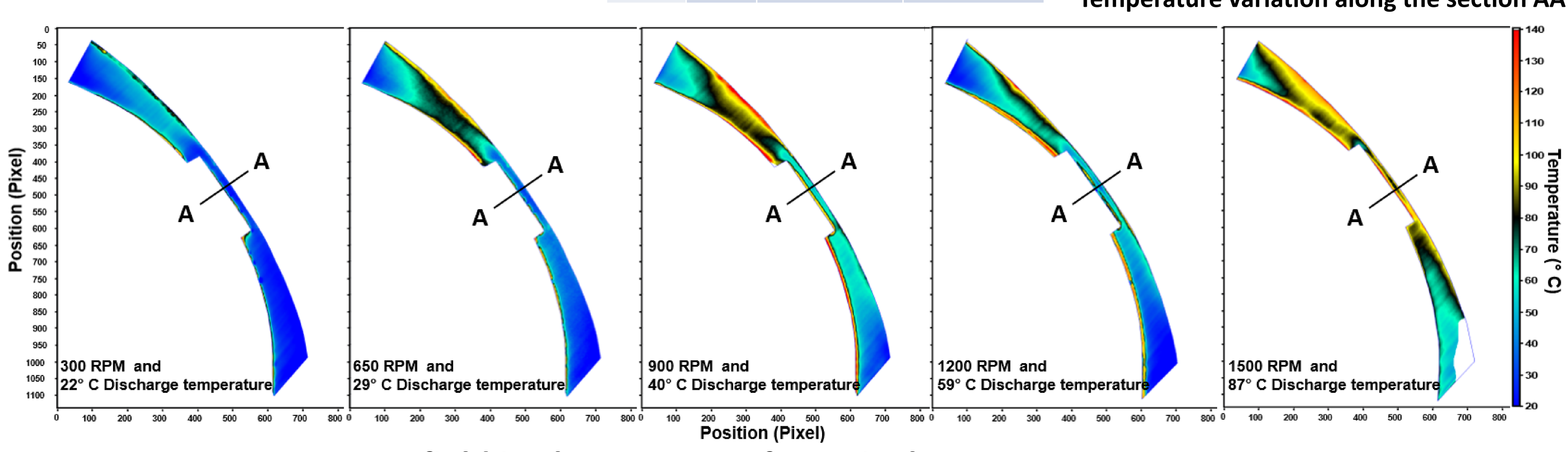
Arrangement of optics and Roots blower for single camera LIF imaging and measurement

- Anisole fluorescence was seeded using a Bronkhorst anisole seeder
- Nitrogen was supplied as co-flow with anisole
- Need to change filters (320 & 280nm) for each operating condition

Single Camera Test conditions			
Speed	Filter	Discharge pressure (barg)	Discharge temperature (°C)
300	320	1.04	22
	280	1.04	22
650	320	1.11	29
	280	1.11	27
900	320	1.18	37
	280	1.18	40
1200	320	1.29	59
	280	1.29	53
1500	320	1.43	80
	280	1.43	87

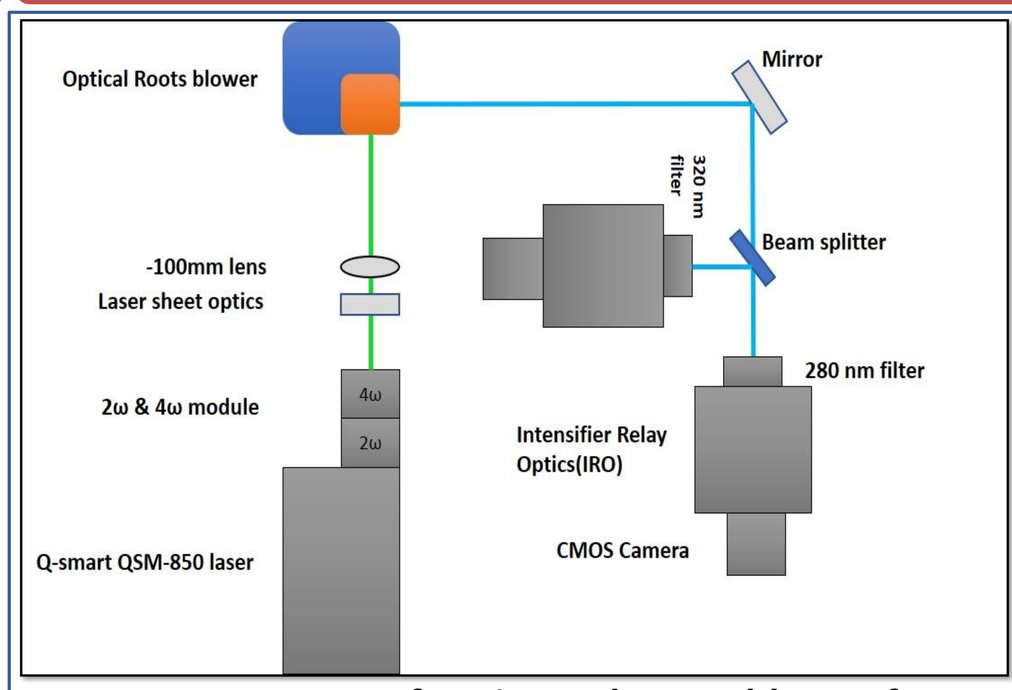


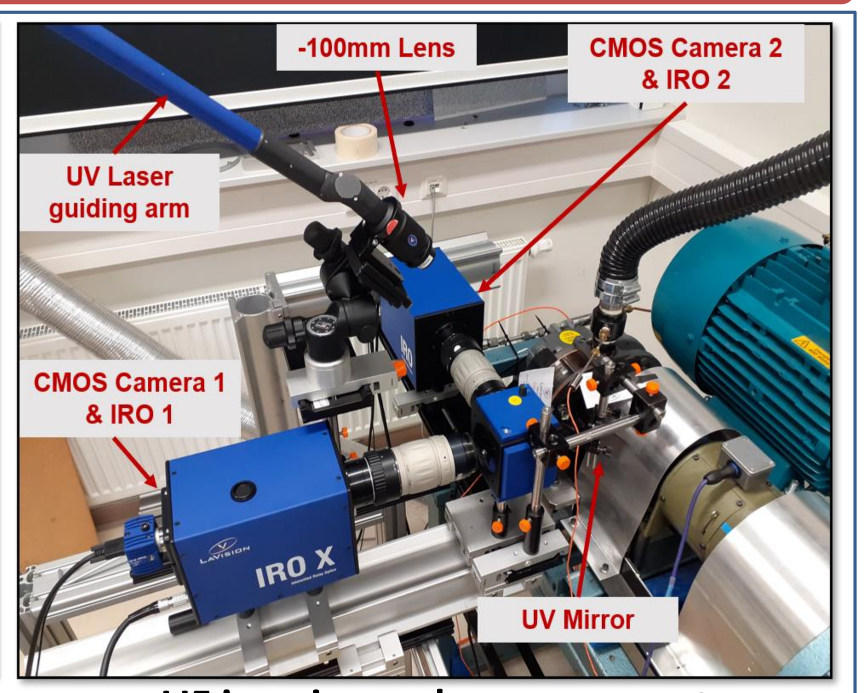
Temperature variation along the section AA



Temperature field in clearance gap from single camera LIF measurement

6. Two camera LIF test setup and results

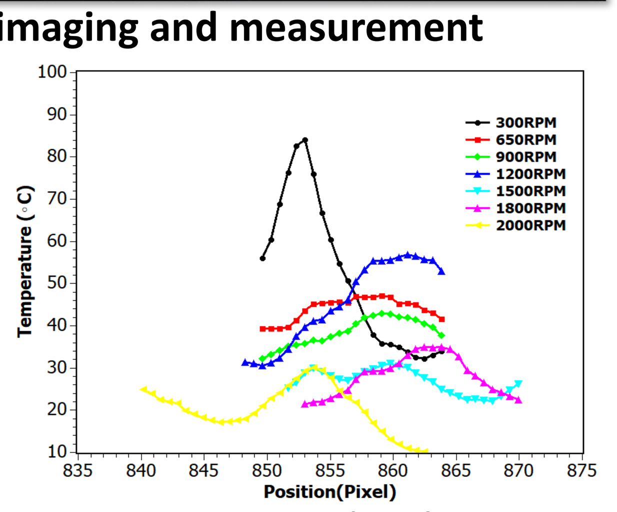




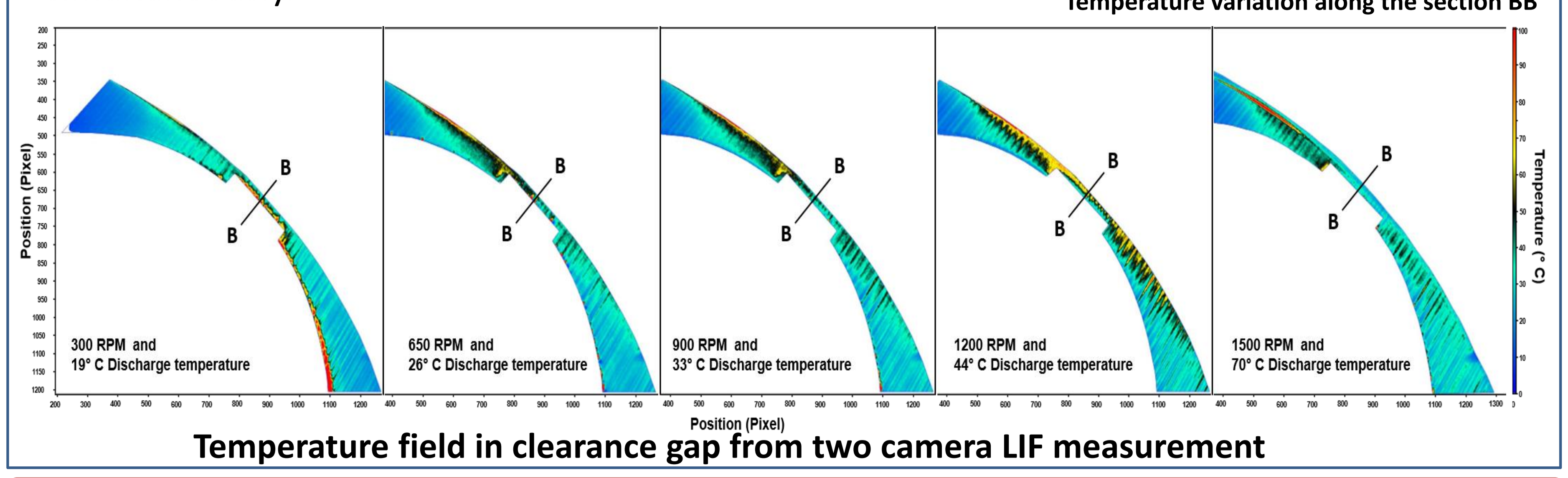
Arrangement of optics and Roots blower for two camera LIF imaging and measurement

- Anisole fluorescence was seeded using a Bronkhorst anisole seeder
- Air was supplied as co-flow with anisole to avoid oxygen quenching
- No need to change filters (320 & 280nm) for each operating condition, image can be captured by two filters simultaneously.

Two Camera Test conditions		
Speed	Discharge temperature (°C)	Discharge pressure (barg)
300	18	1.05
650	24	1.09
900	32	1.18
1200	43	1.34
1500	62	1.5
1800	100	1.65
2000	141	1.75



Temperature variation along the section BB



Temperature field in clearance gap from two camera LIF measurement

7. Conclusion

- From single camera LIF test, it is observed that the temperature at the centre of clearance is decreasing in each case. In addition, reflection at suction side(Above section AA) is present.
- Image mapping is not require with single camera setup while it is most important for two camera LIF.
- More glares are observed from two camera LIF results, It is difficult to get temperature detail. Temperature variation along the clearance gap (Section BB) shows random nature.
- PLIF technique can be useful to analyse temperature field inside the clearance in actual operational condition by addressing problems related to the temperature calibration and image mapping.

8. References

1. Sun, G. Singh, A. Kovacevic, and C. Bruecker, "Experimental and Numerical Investigation of Tip Leakage Flows in a Roots Blower," Designs, vol. 4, no. 1, p. 3, 2020.
2. C. Schulz and V. Sick, "Tracer-LIF diagnostics: Quantitative measurement of fuel concentration, temperature and fuel/air ratio in practical combustion systems," Prog. Energy Combust. Sci., vol. 31, no. 1, pp. 75–121, 2005.
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