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Infrared Emission Detection as a Fuel-Vapor Penetration Diagnostic

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Line-of-sight infrared (IR) imaging near 3.39 microns captures natural C-H stretch-band emission of hot fuel jets for quantification of jet penetration [Klingbeil 2007]. Simultaneous imaging of volume-illuminated laser-induced fluorescence (VLIF) of trace impurities in the n-dodecane fuel provides for comparison along the same optical path as the IR line-of-sight. Vapor penetration were determined via IR and VLIF techniques for hole #1 of the Engine Combustion Network (ECN) Spray B injector in a 2.34L optical diesel engine. In the present work, data among various isentropic-core top-dead-center conditions are reported. The comparison of IR and LIF techniques provides benchmark data for the future use of the IR technique to independently determine penetration.

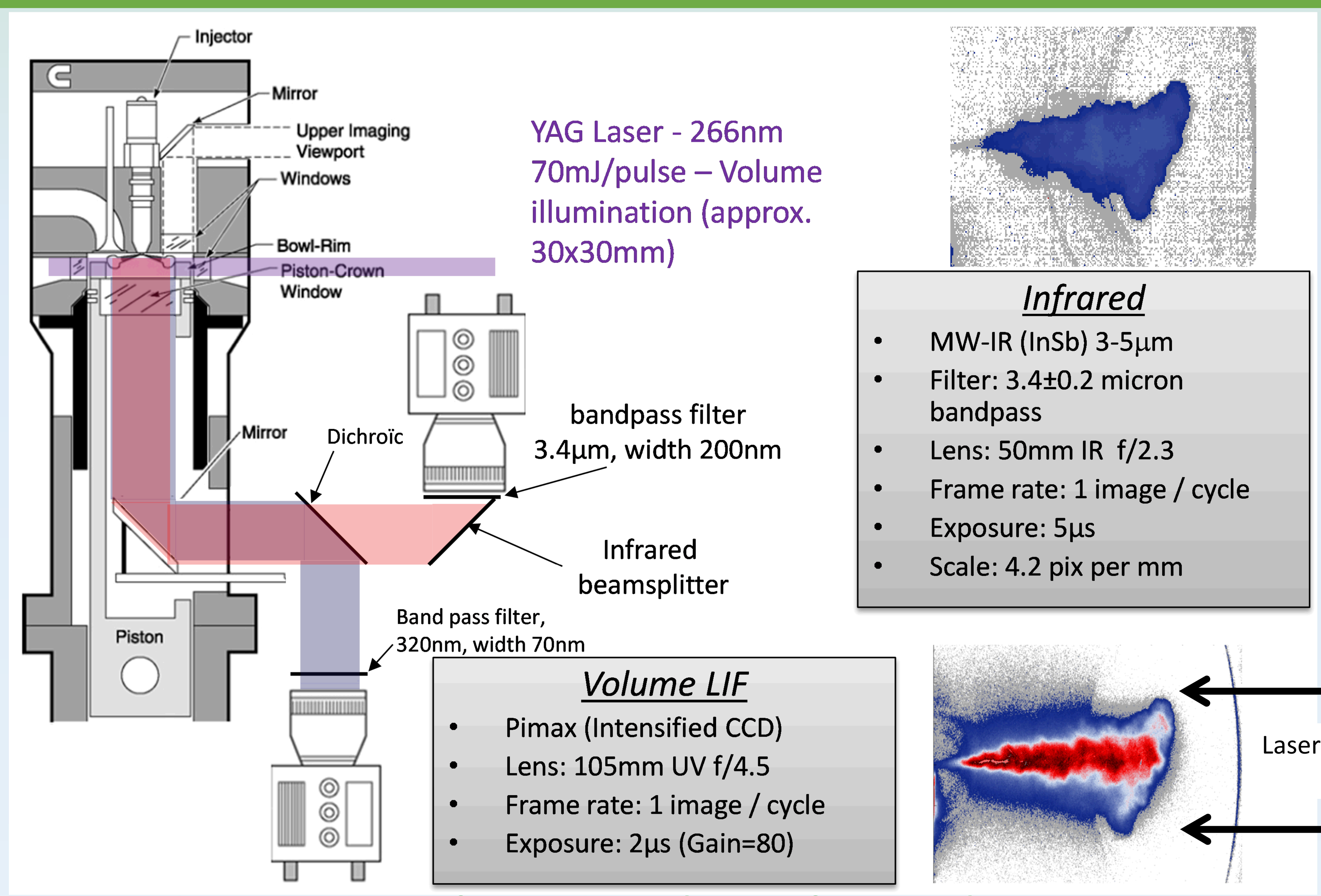

Fig. 1. Engine Schematic and Sample IR and LIF Image

Table 1: Run Conditions

Temperature @ TDC [K]	900	800	1000
Density @ TDC [kg/m^3]	15.2		
Oxygen content [% vol.]	0		
Injector rail pressure [bar]	1500		
Temperature @ IVC [K]	380	340	454
Pressure @ IVC [bar]	2.25	2.01	2.61
Injected liquid mass [mg/cycle]	3.68	3.68	3.68
Engine Speed [rpm]	1200		
Start of Solenoid Energizing [CAD ATDC]	-6.75		
Start of Injection [CAD ATDC]	-5		
Duration of Solenoid Energizing [CAD], [μs]	5.86, 795		
Injection Duration [CAD],[μs]	11, 1500		

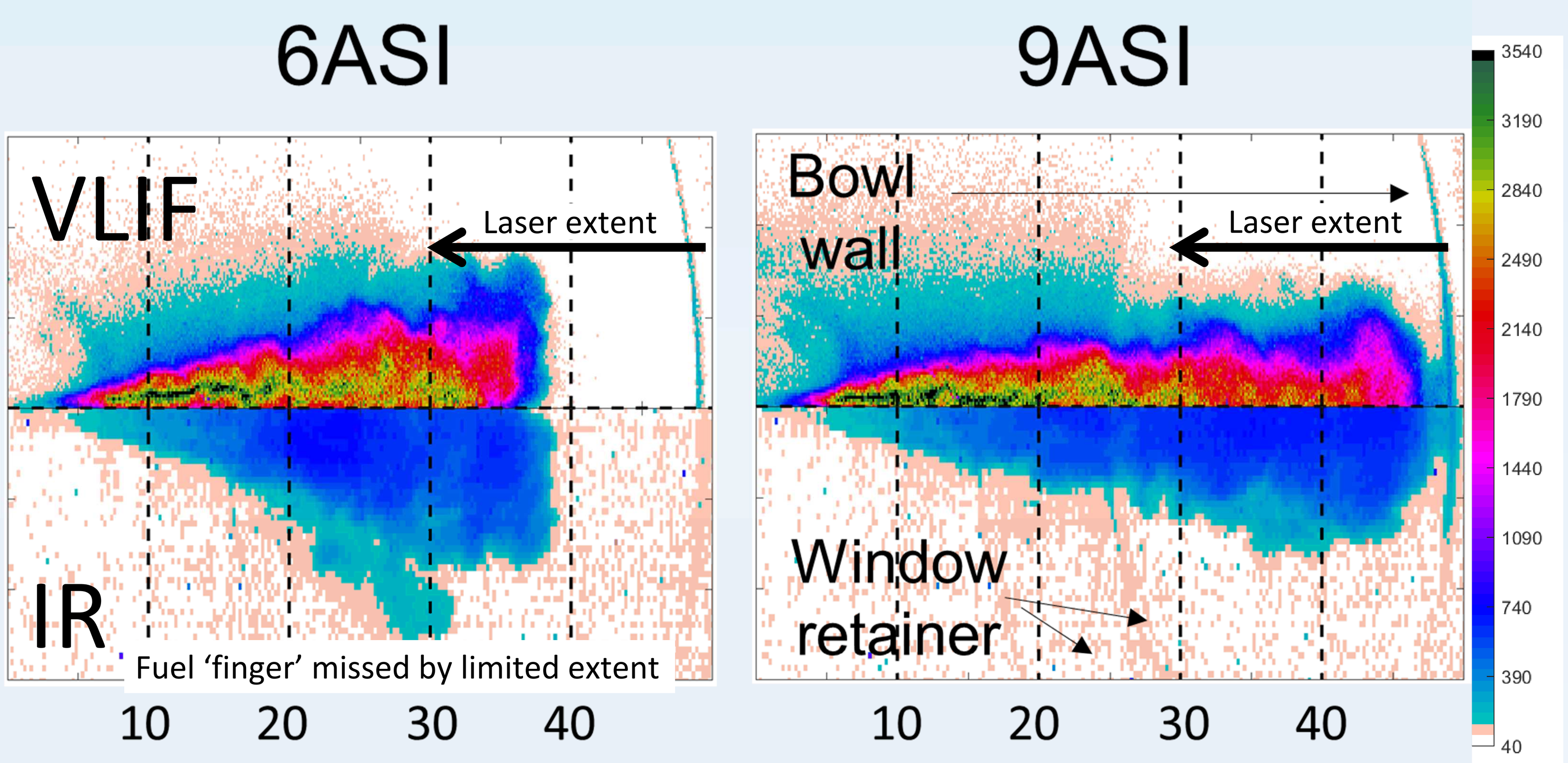

Fig. 2. composite instantaneous images, VLIF and mirrored IR

Instantaneous images of IR and VLIF are compared at two CAD in Fig 2. IR images are displayed as mirrored, such that the same portion of the jet is visible. Ensemble average centerline profiles from 30 repetitions of IR and LIF are shown in Figure 3. The differences in both the slope and location of the maximum intensities along this profile are due to fuel-vapor temperature effects. For the LIF signal with a tracer, an increase in temperature results in a weakening signal [Musculus 2007], while a simple IR model (Fig. 4) of natural emission predicts emission is increases with distance from the injector and is proportional to both temperature and emitter concentration. Thus along the profiles, the LIF signal peaks early and declines, while the IR signal rises steadily until the tip of the jet, or to the maximum temperature. Also note in Fig 4 that the slope changes at the interface of background materials, with the IR-reflective metal giving a slightly higher signal than the IR-transparent window. Comparing tip penetrations in Fig 5. the two techniques yield comparable results.

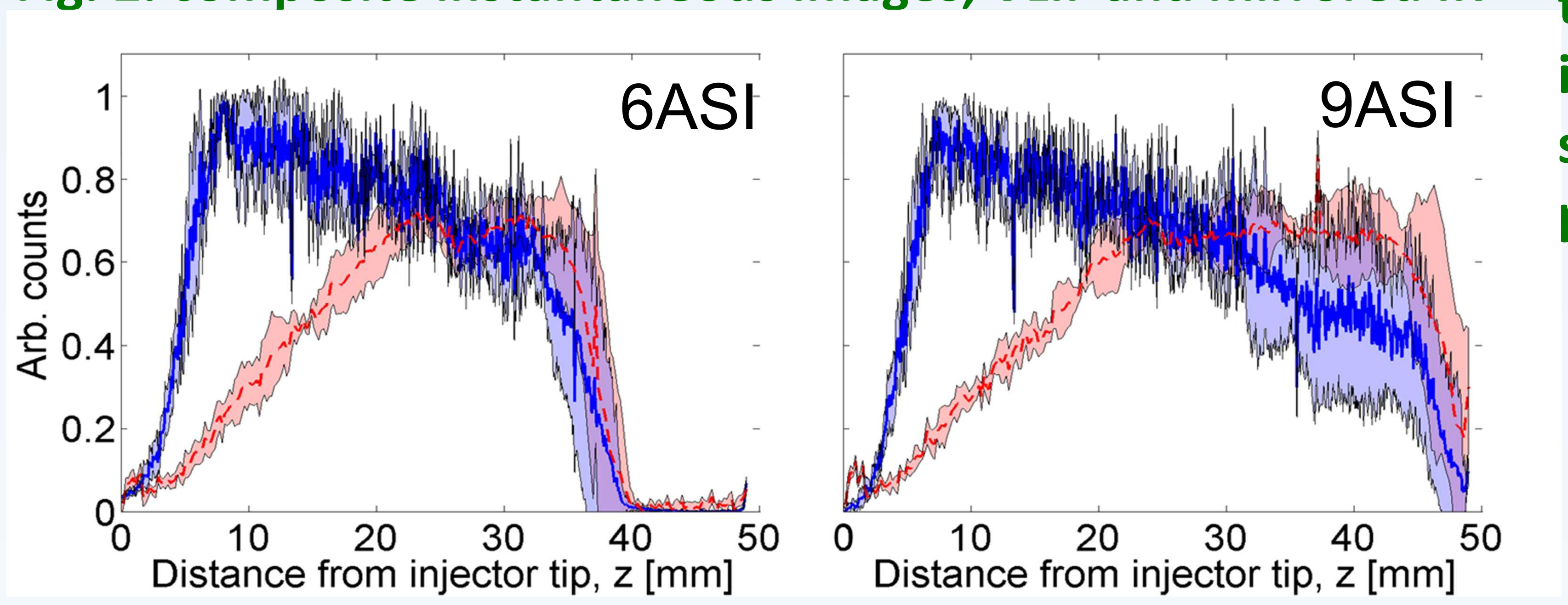

Fig. 3. Normalized ensemble-average emission along the jet axis. Blue-VLIF, Red-IR

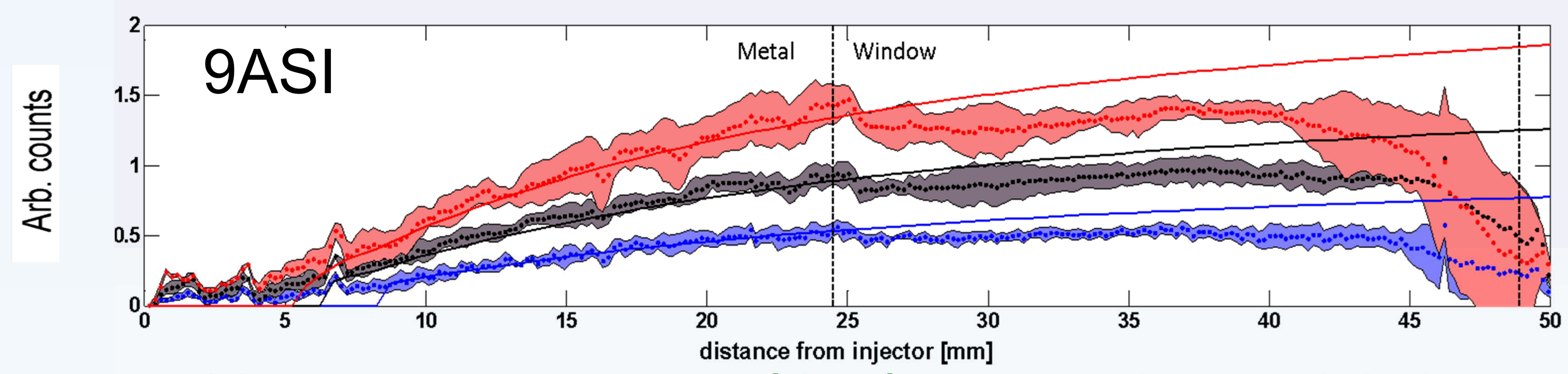

Fig. 4: Ensemble average IR intensity (dots) compared to modeled IR emission (lines) from a steady developed free jet. Red-1000K Black-900K, Blue-800K

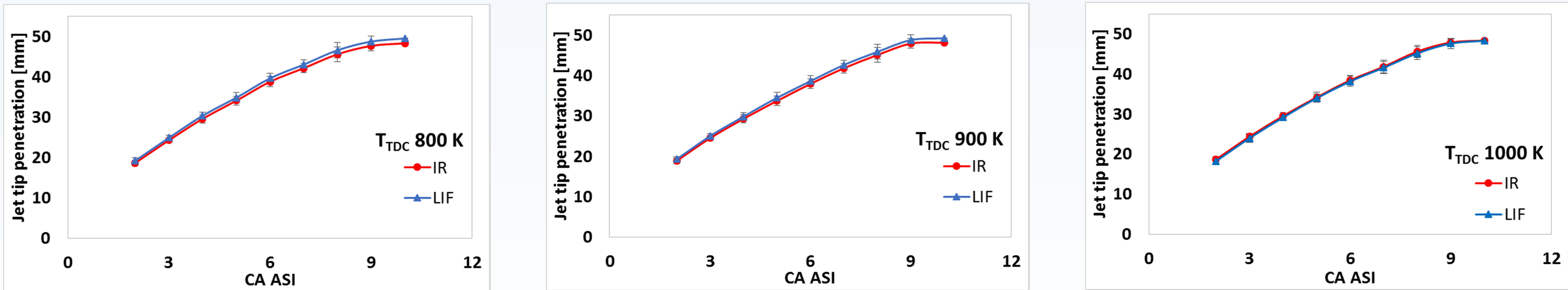

Fig. 5: Jet tip penetrations with IR and LIF varying in-cylinder temperatures from 800 to 1000K.

Summary and Conclusions:

No external source is needed to illuminate evaporating fuel for IR detection near TDC.
Some differences exist due opposite effects of temperature on signal strength of VLIF vs IR.
IR emission yields comparable penetration detection to VLIF under non-reacting conditions.

References:

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Musculus, MPB, Lachaux T, Pickett, LM and Idicheria, CA (2007) End-of-injection over-mixing and unburned hydrocarbon emissions in low-temperature-combustion diesel engines. SAE Paper 2007-01-0907, SAE Trans. 116(3):515-541.

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