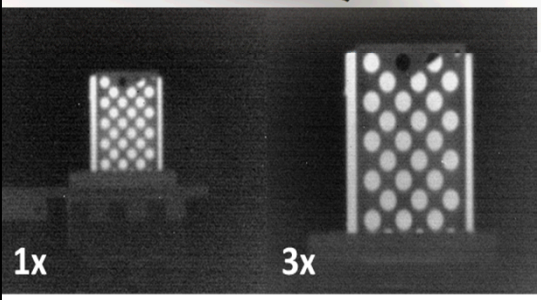
SAND2014-18495C



Adaptive Polymer Lenses for Tactical use in the Midwave IR

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10/06/14

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Exceptional service in the national interest

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Need

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Motivation

- No tactical variable field of view systems for the SWIR and MWIR
- Low SWaP camera based systems
- Operators forced to trade situational awareness for target identification
- Adaptive zoom offers:
  - Weight reduction
  - Push button instant change
  - Situational awareness and target identification

Materials Challenge

- Fluid
  - High transmission
  - Compatible with membrane
  - Diffusion
  - Optical properties (high n)
- Flexible membrane

Adaptive Polymer Lenses

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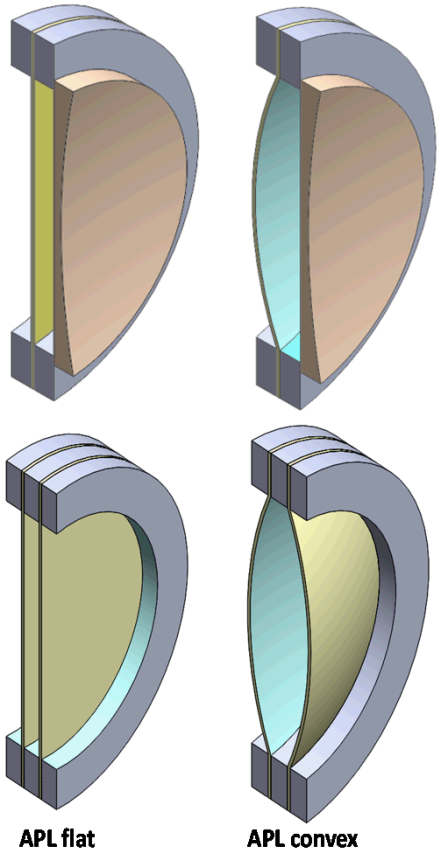
- Fluidic optical element with flexible membranes which vary its radius of curvature (ROC)
- Description:
  - One or two pre-strained PDMS membranes, single fluid
  - Clear aperture(CA): 23.77 mm (with actuation plunger: 19 mm)
  - Typical dynamic range:
    - Diopters: -5 to 28 Diopters
    - Focal length range: -200 to 35 mm
- Properties:
  - index of refraction (2), Abbe number (2)
- Large optical change can be achieved with a small mechanical movement



Example Application

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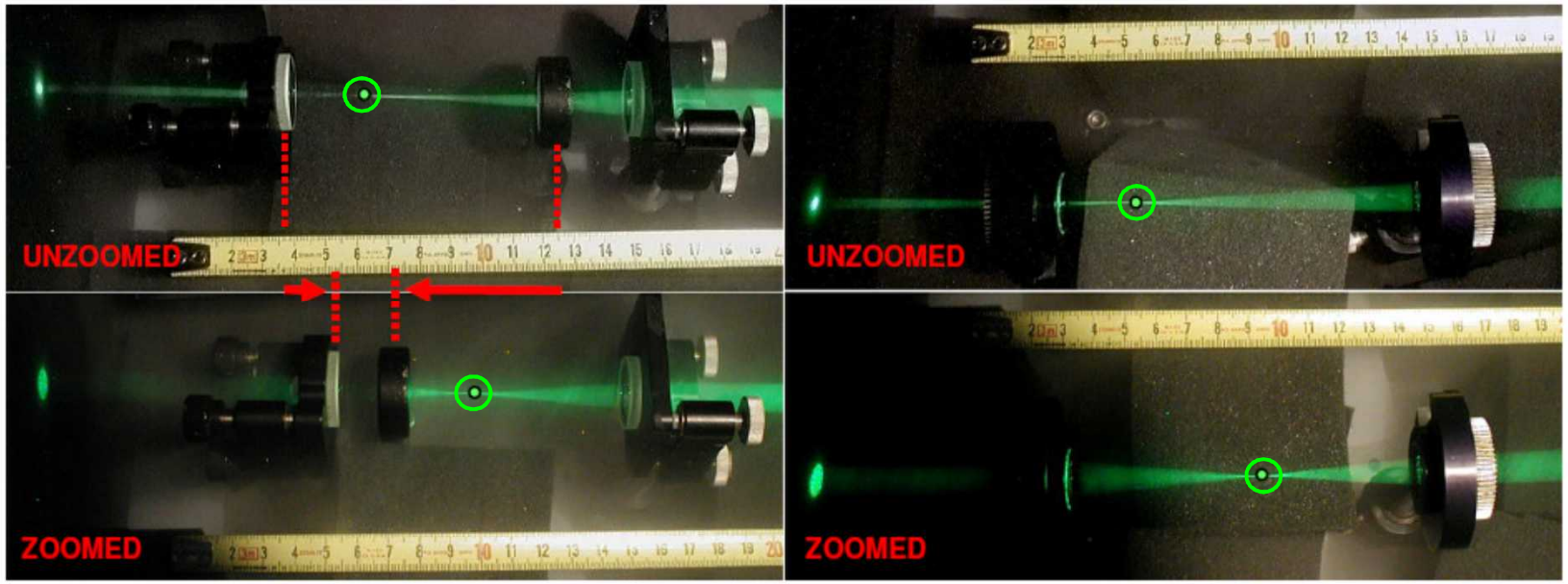
Conventional zoom

Adaptive zoom



Example: *Two 3X Zoom Modules (Afocal), Each 12" in length*

- The mechanical zoom (LEFT) translates through ~70 mm
- The variable focal length zoom (RIGHT) longitudinally compresses ~ 0.7mm
- **Two orders of magnitude reduction**

Fluid Selection Criteria

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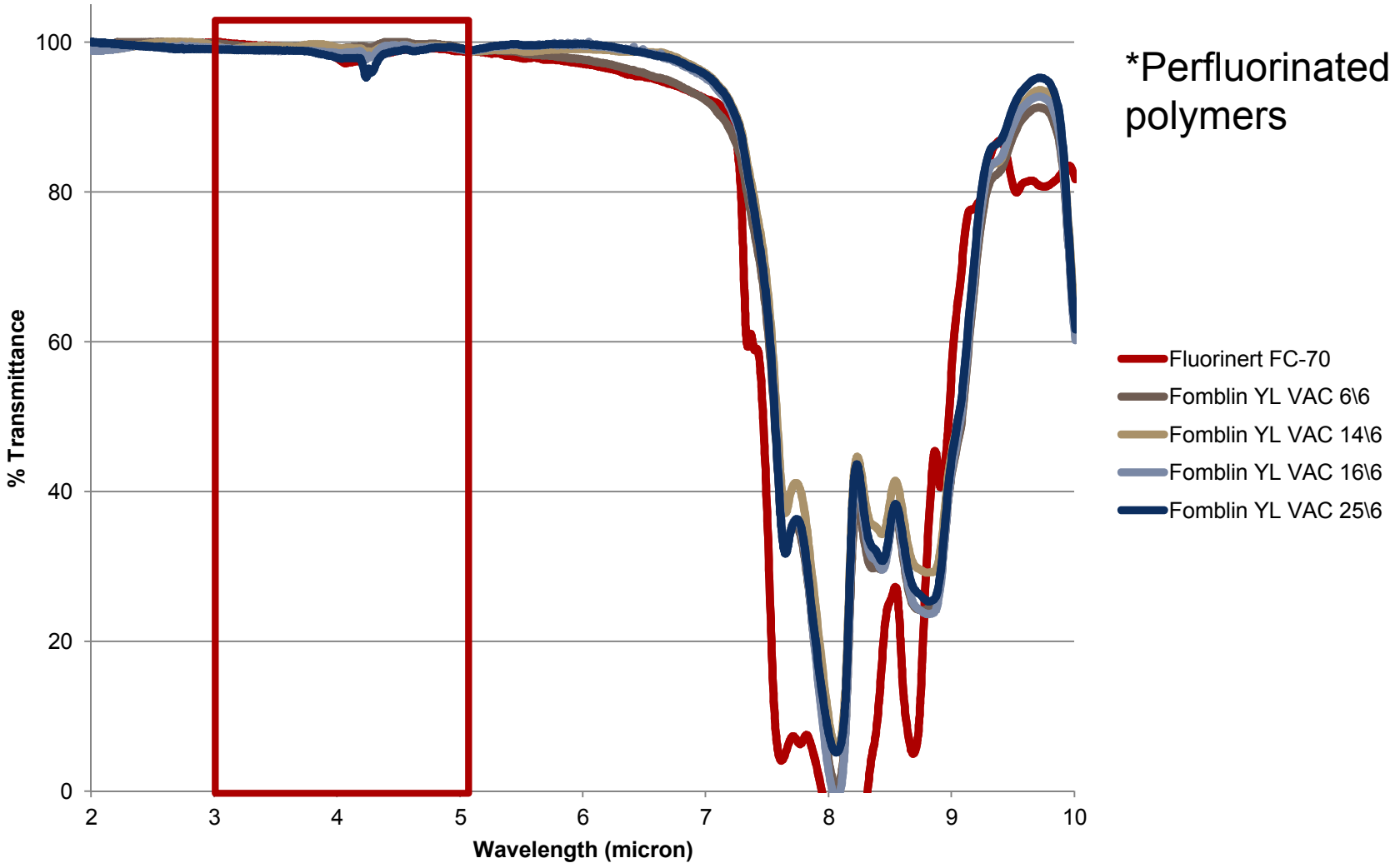
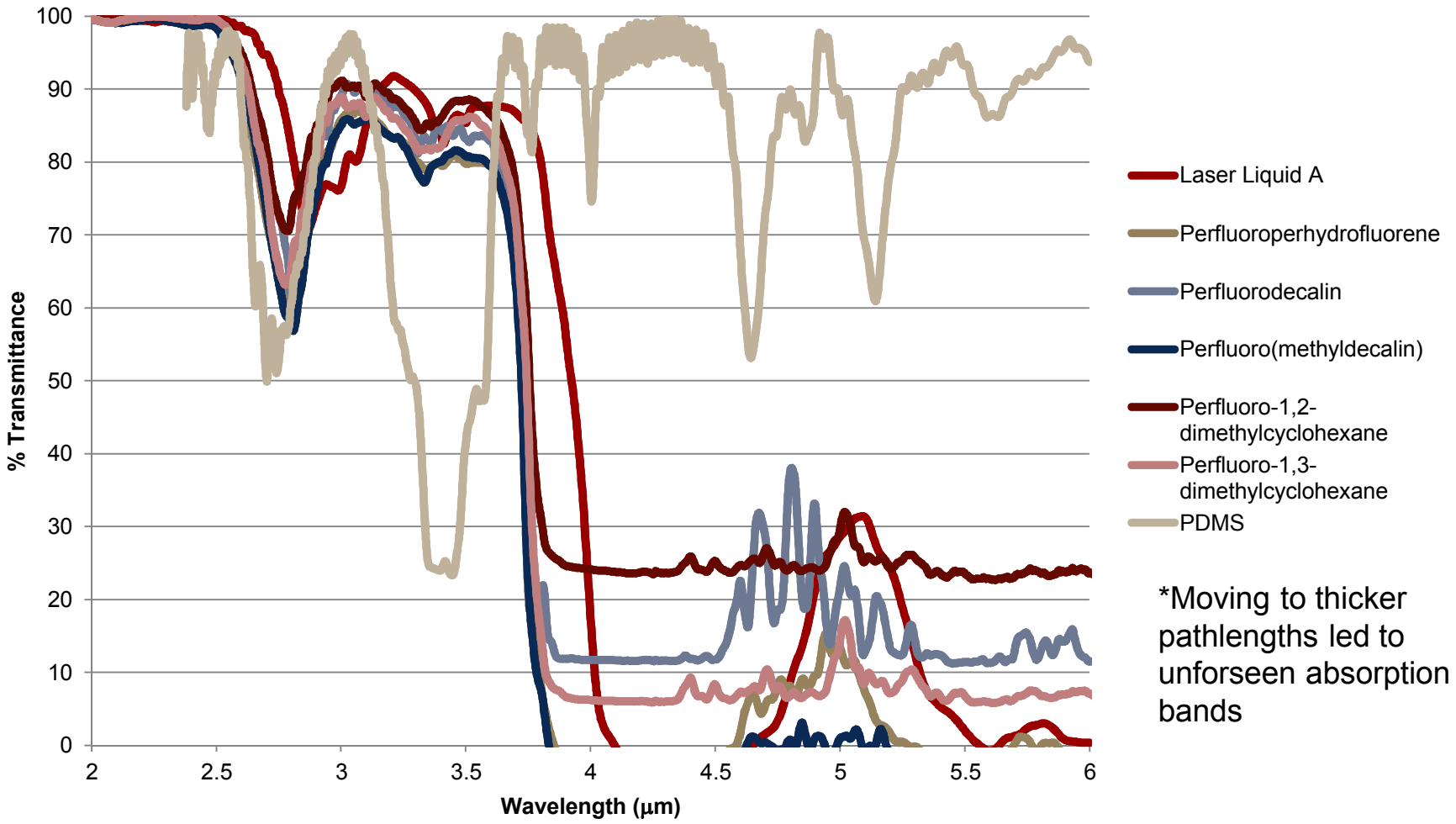
- Absence of C-H, O-H, N-H, C=C bonds (based on IR functional group absorption tables)
- Compatibility with PDMS (Polydimethylsiloxane) – can be swollen, optical properties can change, mechanical properties/integrity can change
- Size/molecular weight – larger compounds less likely to diffuse
- n_D, CTE, Abbe number, dn/dT

Thin Film Transmission IR



Bulk Transmission IR



*Moving to thicker pathlengths led to unforseen absorption bands

Unexpected Absorbances

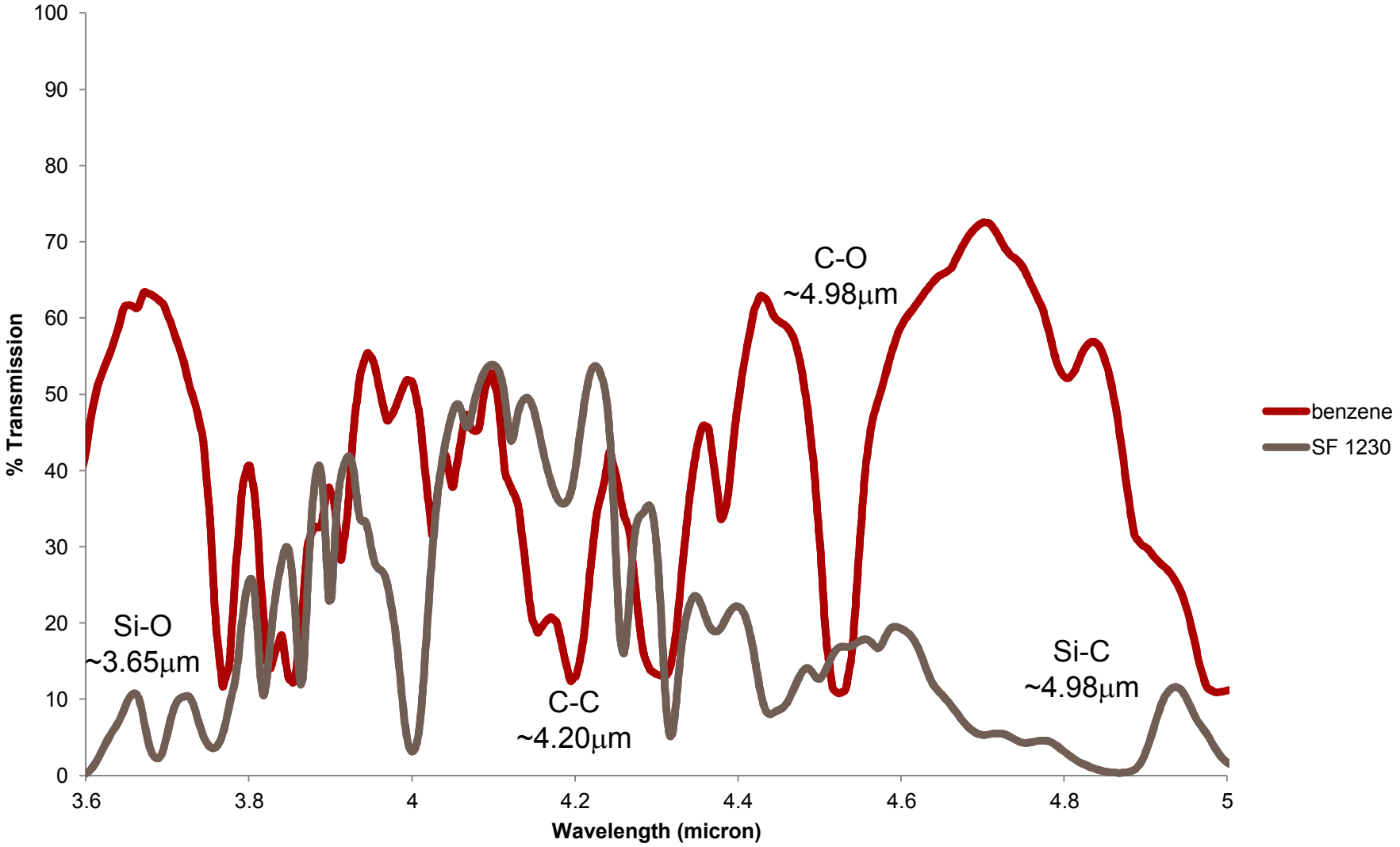
- Overtone peaks- second and higher order excited states
  - Magnified when transmitting through bulk material
  - Using Hooke's Law, predicted stretching frequencies of bonds were calculated $v = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

Hooke's Law

29979245800	speed of light (cm/s)
3.141592654	pi
5.00E+05	single bond
1.00E+06	double bond
1.50E+06	triple bond

				1st excited state		2nd overtone		3rd overtone	
Atomic Wt 1	Atomic Wt 2	mass 1	mass 2	vib freq (cm-1)	wavelength		Overtone	Overtone micron	Overtone	Overtone micron
12.011	1.00794	1.9952E-23	1.6743E-24	3020.393768	3.31082659	C-H bond	6040.78754	1.655413295	9061.1813	1.103608863
15.9994	1.00794	2.6577E-23	1.6743E-24	2991.105181	3.343245856	O-H bond	5982.21036	1.671622928	8973.31554	1.114415285
12.011	12.011	1.9952E-23	1.9952E-23	1188.524369	8.413794667	C-C bond	2377.04874	4.206897333	3565.57311	2.804598222
28.0855	15.9994	4.6654E-23	2.6577E-23	912.2937055	10.96138222	Si-O	1824.58741	5.480691109	2736.88112	3.653794072
28.0855	12.011	4.6654E-23	1.9952E-23	1004.165383	9.958518958	Si-C	2008.33077	4.979259479	3012.49615	3.319506319
28.0855	1.00794	4.6654E-23	1.6743E-24	2952.716792	3.386711529	Si-H bond	5905.43358	1.693355764	8858.15038	1.128903843
12.011	12.011	1.9952E-23	1.9952E-23	1680.827282	5.949451265	C=C double	3361.65456	2.974725632	5042.48185	1.983150422
12.011	15.9994	1.9952E-23	2.6577E-23	1111.990048	8.992886242	C-O	2223.9801	4.496443121	3335.97014	2.997628747
12.011	15.9994	1.9952E-23	2.6577E-23	1572.591406	6.358930844	C=O double	3145.18281	3.179465422	4717.77422	2.119643615
12.011	18.9984032	1.9952E-23	3.1559E-23	1073.695782	9.313625118	C-F	2147.39156	4.656812559	3221.08734	3.104541706
28.0855	28.0855	4.6654E-23	4.6654E-23	777.2425973	12.86599581	Si-Si	1554.48519	6.432997905	2331.72779	4.28866527
28.0855	14.00674	4.6654E-23	2.3267E-23	952.7393043	10.49605066	Si-N	1905.47861	5.248025328	2858.21791	3.498683552
28.0855	35.4527	4.6654E-23	5.8892E-23	735.7569826	13.59144424	Si-Cl	1471.51397	6.795722118	2207.27095	4.530481412
72.61	72.61	1.2061E-22	1.2061E-22	483.391997	20.68714431	Ge-Ge	966.783994	10.34357216	1450.17599	6.89571477
72.61	12.011	1.2061E-22	1.9952E-23	907.2645698	11.02214319	Ge-C	1814.52914	5.511071595	2721.79371	3.67404773
72.61	15.9994	1.2061E-22	2.6577E-23	804.400826	12.43161329	Ge-O	1608.80165	6.215806645	2413.20248	4.143871097
72.61	14.00674	1.2061E-22	2.3267E-23	849.995921	11.76476234	Ge-N	1699.99184	5.882381169	2549.98776	3.921587446

Correlating Absorbances



VPL Cell

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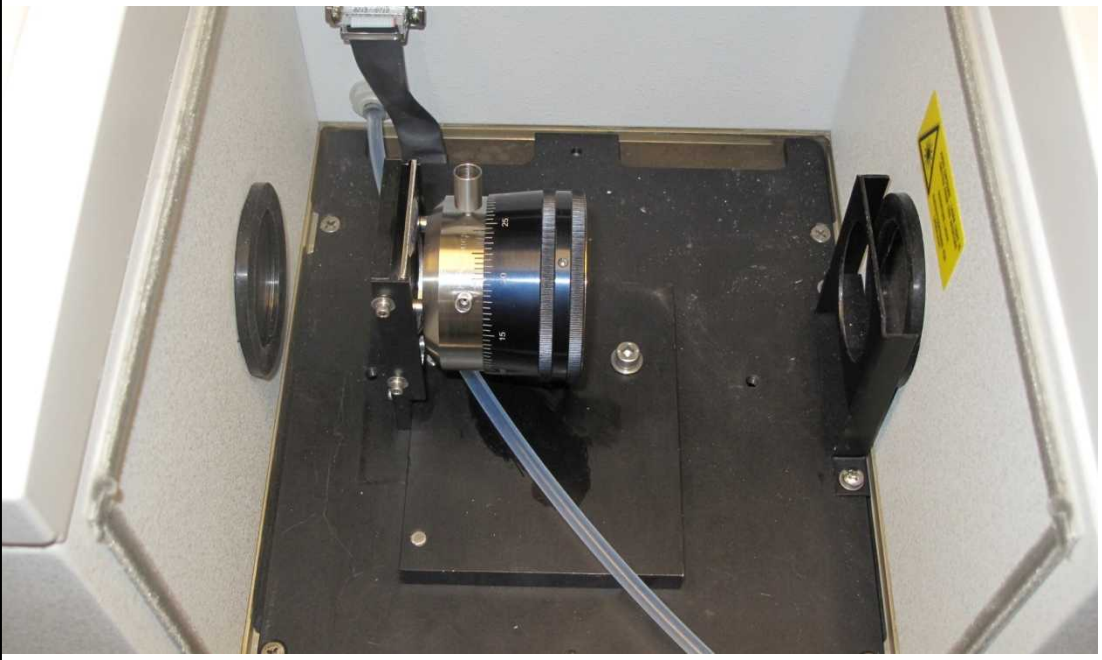
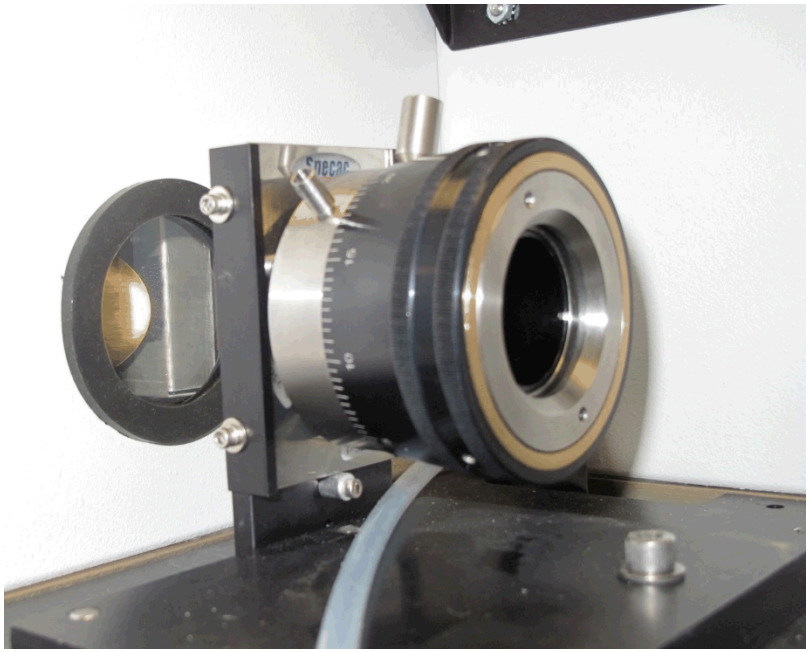
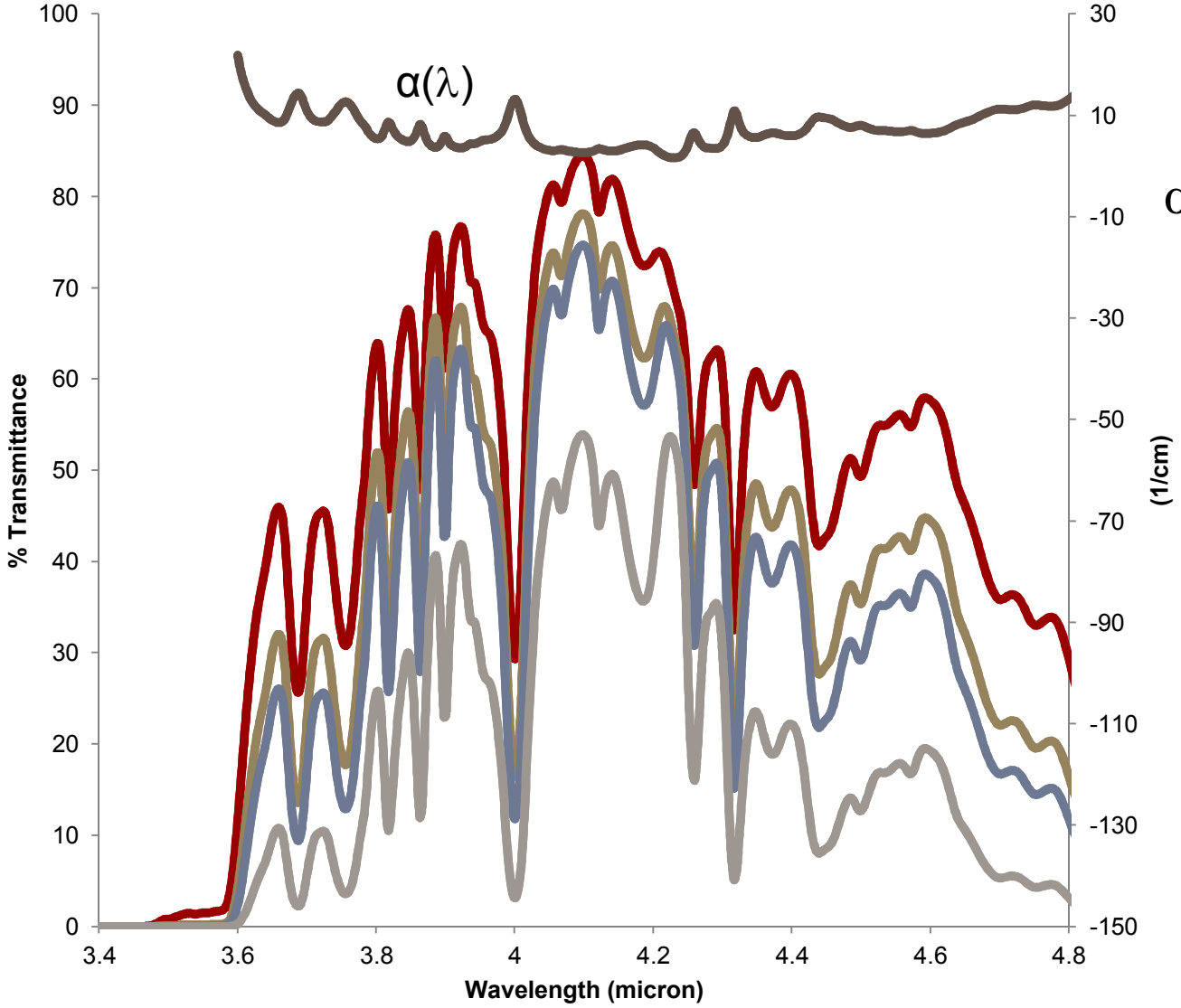




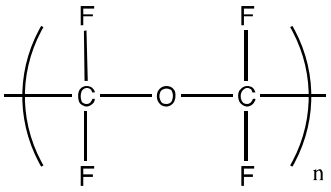
Allowed for absorption to be measured at various path lengths
-Extinction coefficient vs. wavelength

Fluid Used

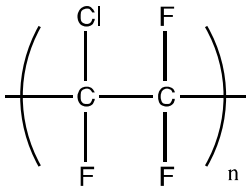


$$\alpha(\lambda) = \frac{\ln(T_1 \times \frac{1}{T_2})}{L_2 - L_1}$$

Other Polymeric Fluids Explored

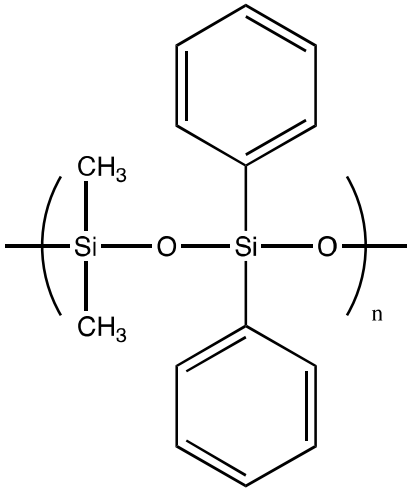


PFPE

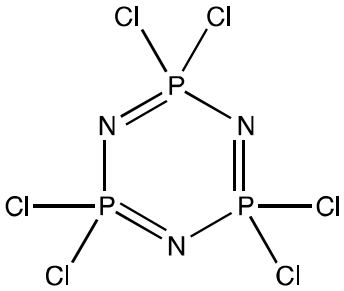


PCTFE

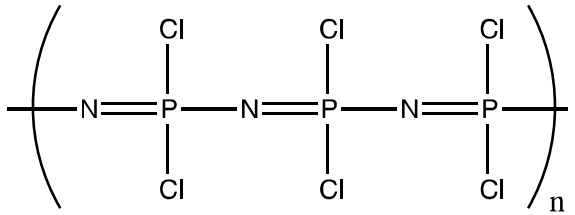
Commercial and non-commercial



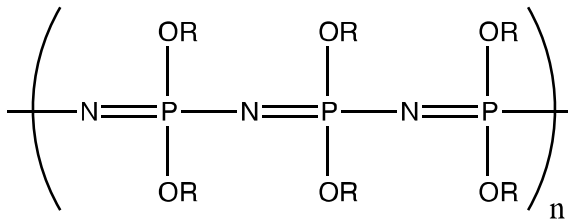
Methyl phenyl polysiloxane



250°C



excess $^{-}$OR
dioxane



Class of relatively new unexplored polymers

Can modify R to tailor properties

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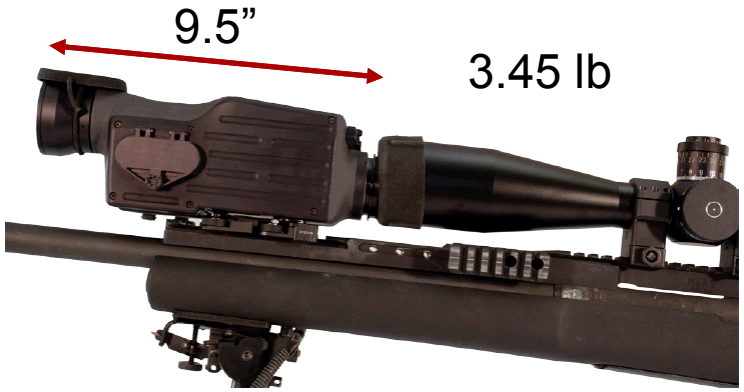
MWIR System

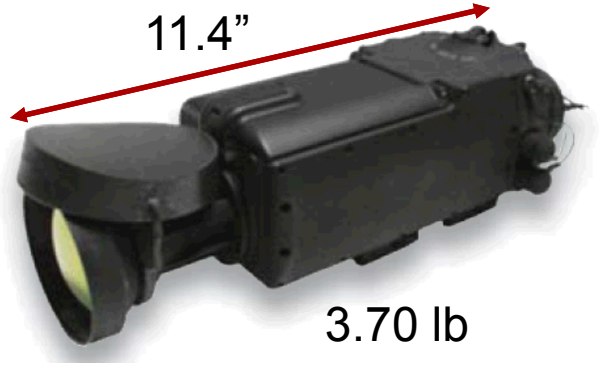
MWIR Motivation

- MWIR is emissive
  - No external illumination required
- Imaging dependent on emissivity of materials
  - Two objects at same temp don't radiate the same energy (contrast)
- Can be used to detect the absence of heat
- Temperature differences as low as 0.02ºC readily detectable
- Current system lack the capability of target identification (fixed FOV)

DRS



FLIR



MWIR Breadboard

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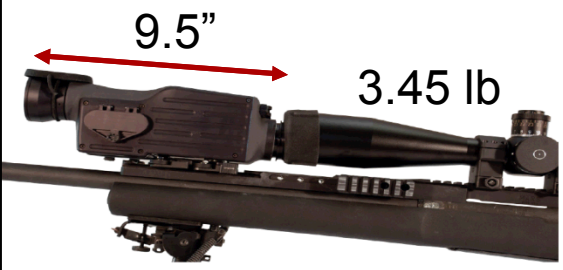
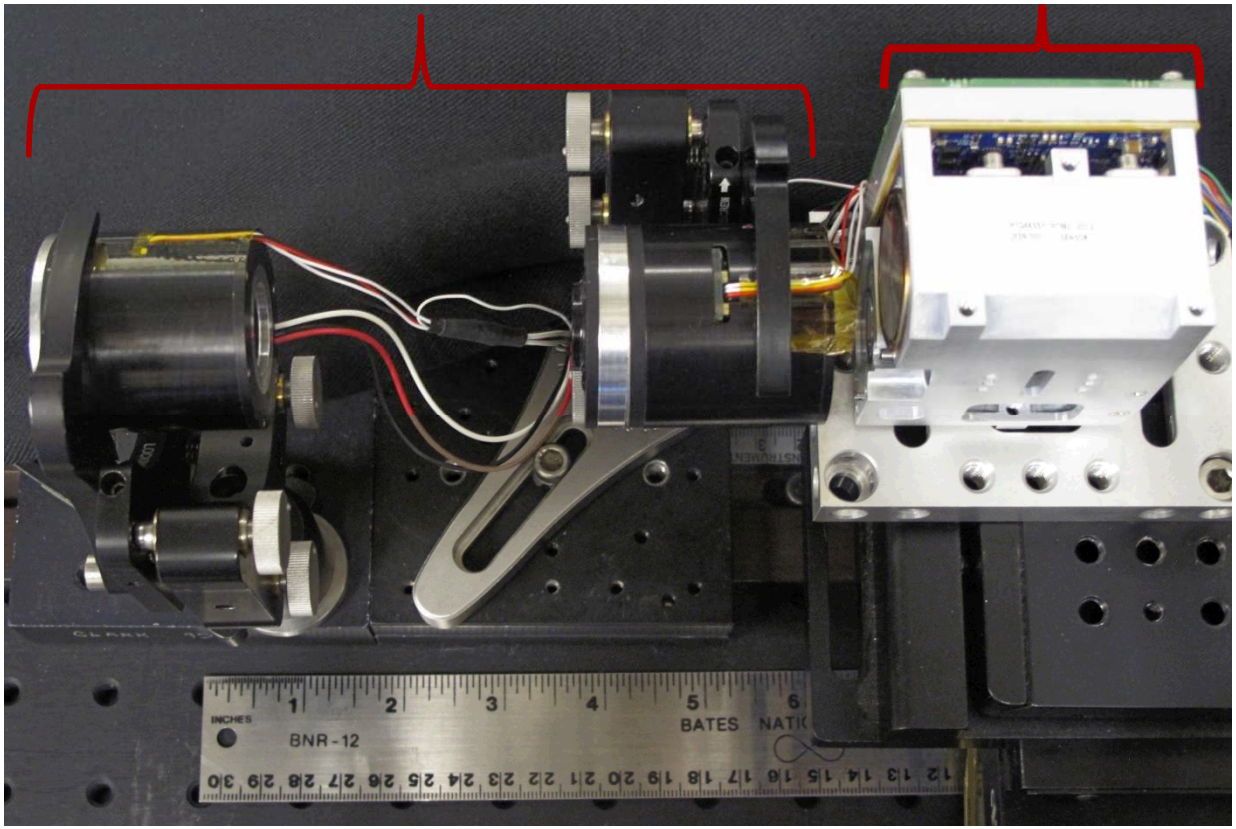
System length: 8.2”
Approximate Weight of components: 1.40 lb.
FOV:1-3˚



MWIR APLs

DRS Zafiro Micro
640x480, 12µm pitch
HgCdTe



MWIR Results

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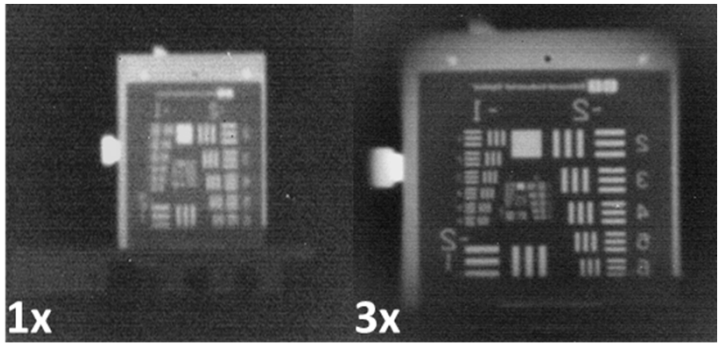

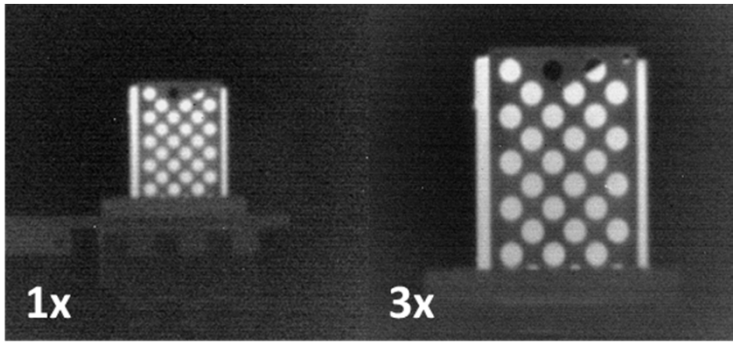

MWIR Results

Acknowledgements

Sandia National Laboratories

- Freddie Santiago
- Brett Bagwell
- NVESD
  - Bruce Pixton
  - Miguel Snider
- DRS Technologies

DRS Technologies
A Finmeccanica Company

Questions?