UPISC UNIVERSITY OF PITTSBURGH INFRASTRUCTURE SENSING

COLLABORATION WORKSHOP

NATIONAL ENERGY TECHNOLOGY LABORATORY

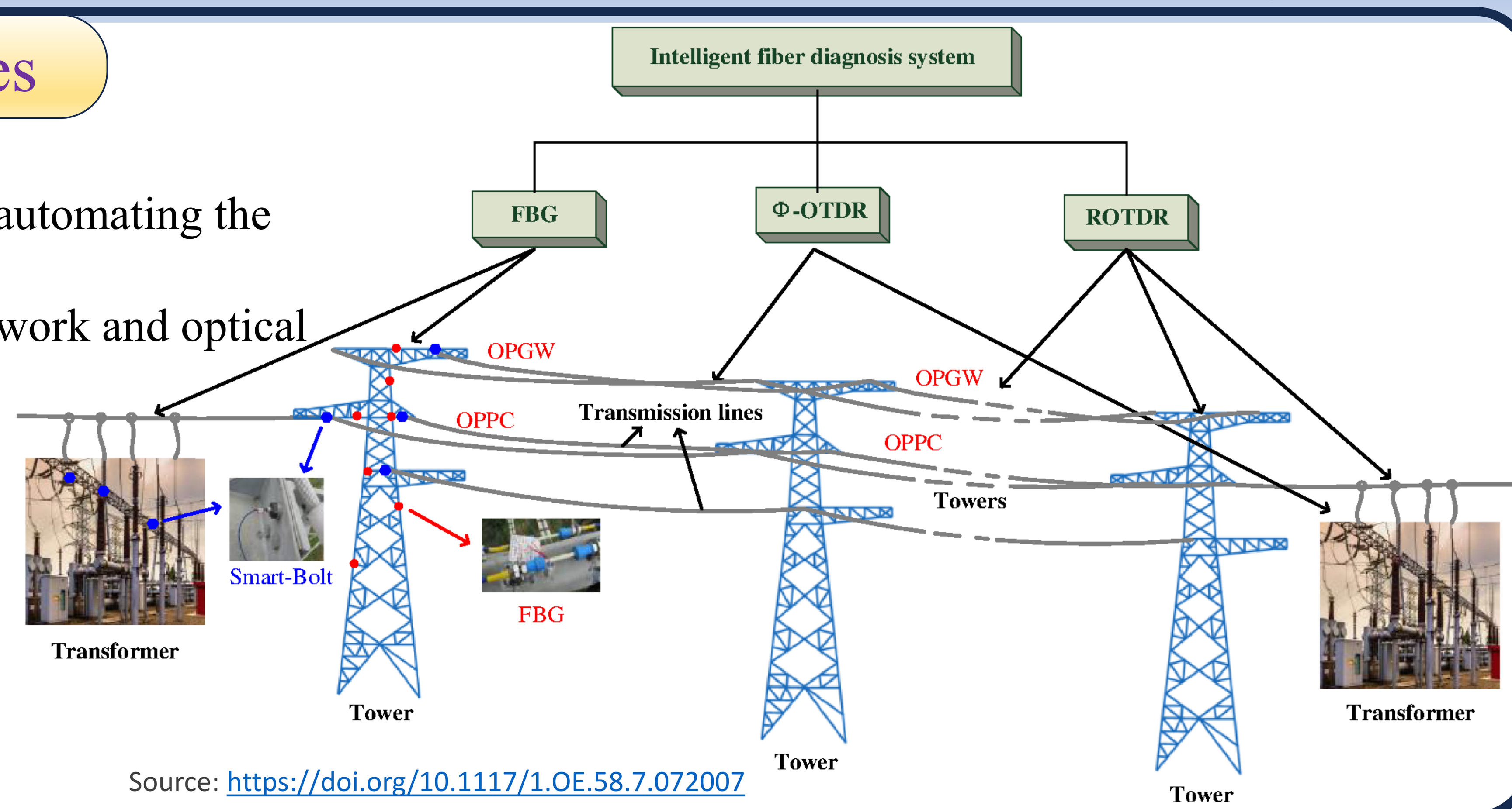
Fiber optic current/magnetic field sensor for Power grid monitoring applications

Dolendra Karki, Tulika Khanikar, Khurram Naeem, Paul Ohodnicki

Univesrity of Pittsburgh, PA, USA

Motivation and Objectives

- Current meter, monitor, control and automating the power grids systems
- Integration to smart grid sensing network and optical fiber communication system
- Reliable and safe delivery of power to consumer level
- Low size, weight and cost
- Immune to EMI



Source: https://doi.org/10.1117/1.OE.58.7.072007

Fiber Optic current sensor architecture

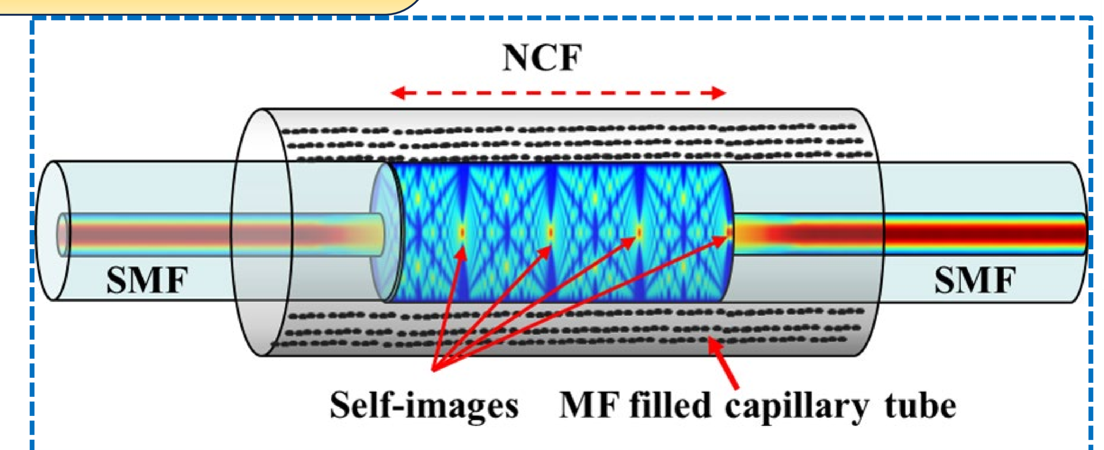
Self imaging in MMI

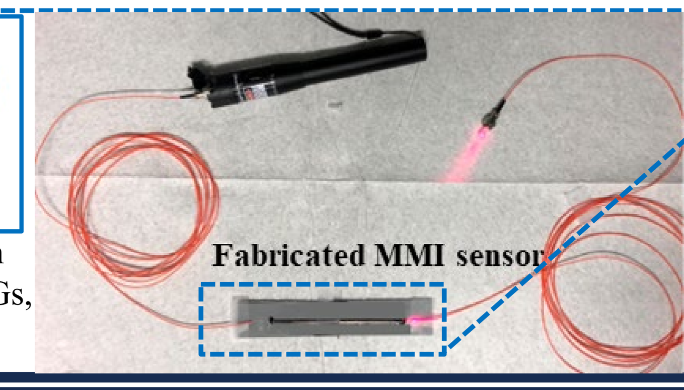
$$L_{MMF} = P\frac{n_{eff}D_{MMF}^2}{\lambda}$$

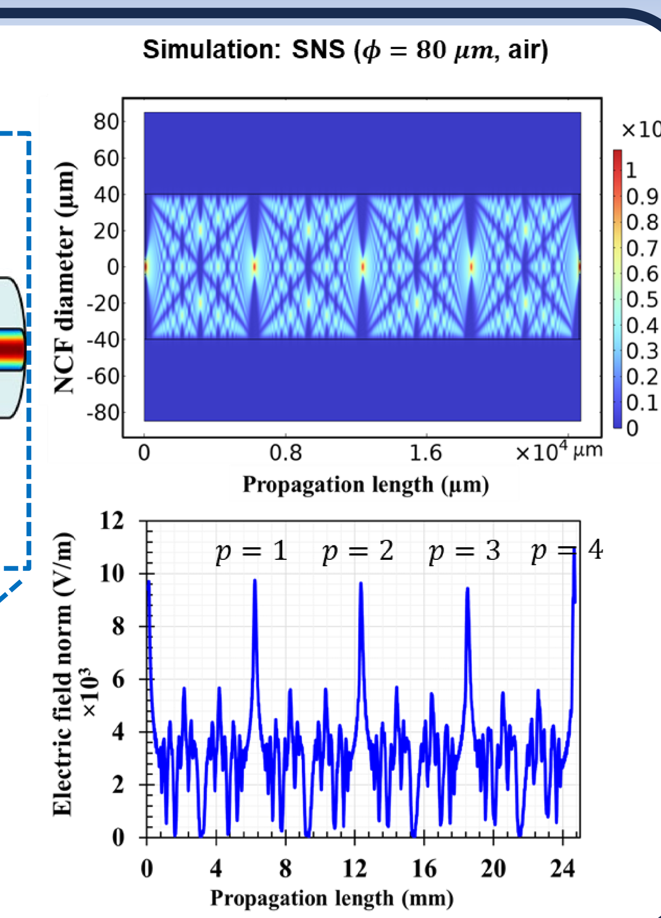
RI of Magnetic fluid (H, T)

$$n_{\mathrm{MF}} = [n_s - n_o]\left[\coth\left(\alpha\frac{H - H_{c,n}}{T}\right) - \frac{T}{\alpha(H - H_{c,n})}\right] + n_o \quad \text{for } H > H_{c,n}.$$

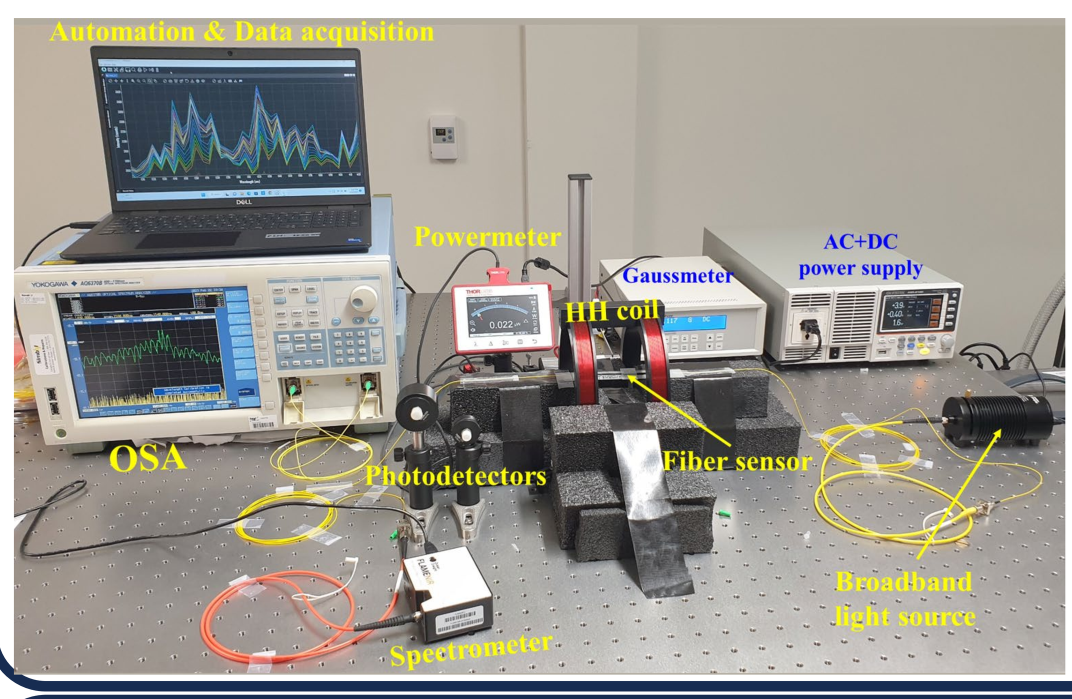
$H_{c,n}$ - critical field strength, n_o - refractive index of MF for fields lower than $H_{c,n}$, n_s - saturated value of the refractive index of MF, H - field intensity in Gs, T - temperature in kelvin, α - the fitting parameter

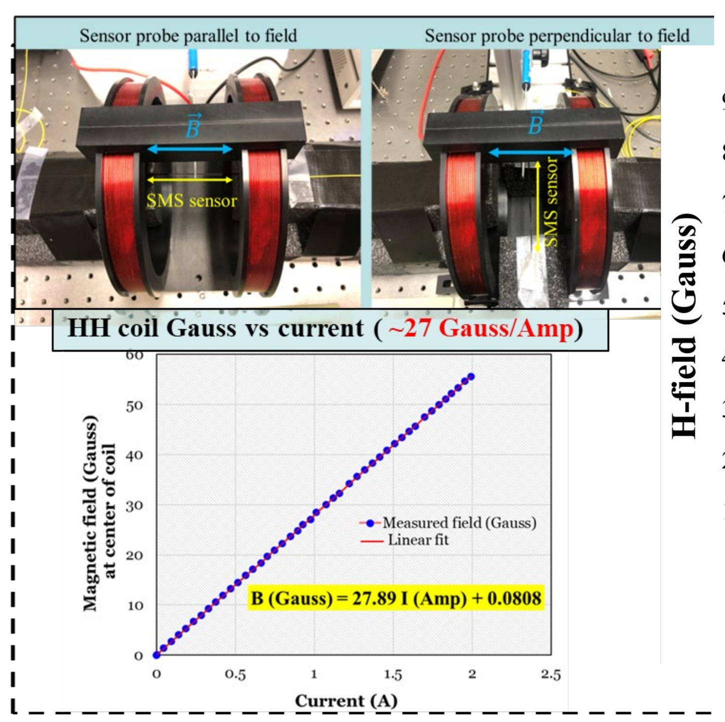


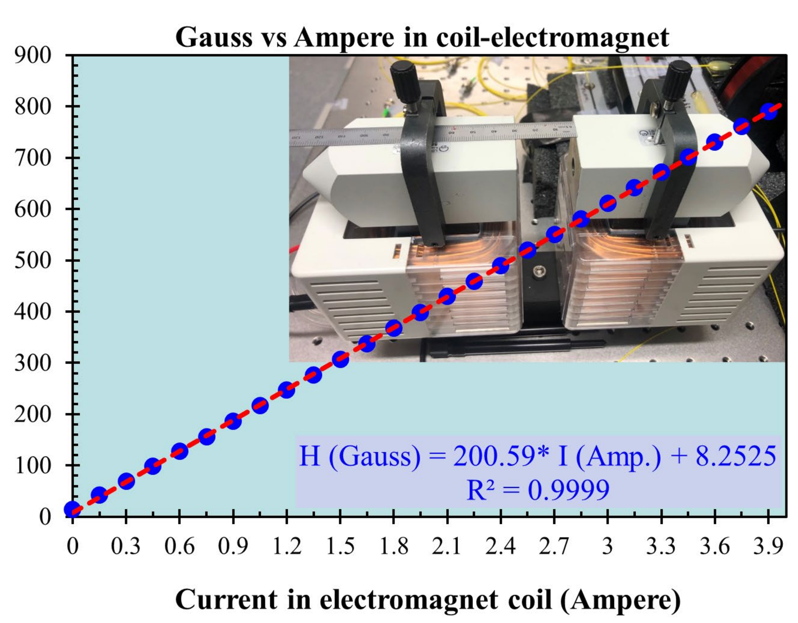




Sensing interrogation set up

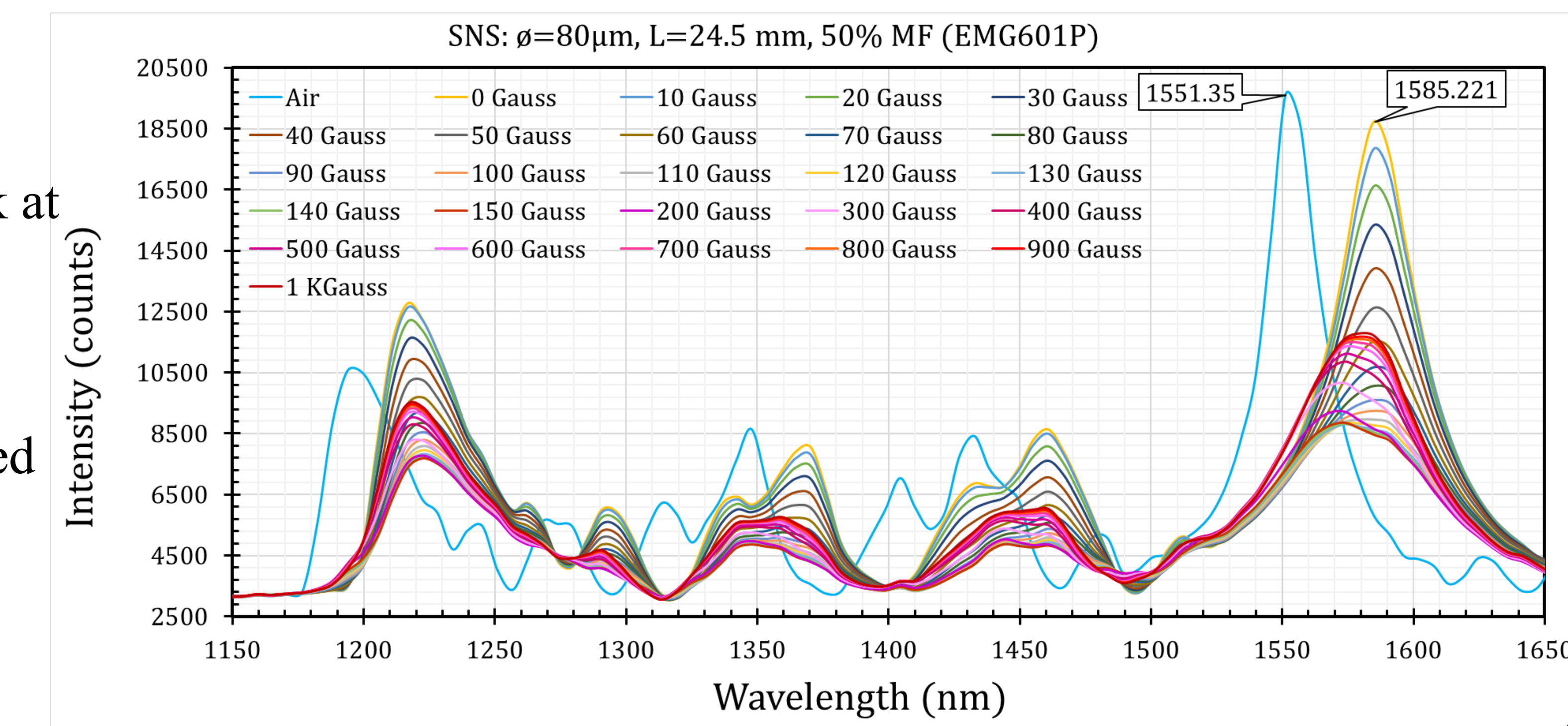






Method of interrogation

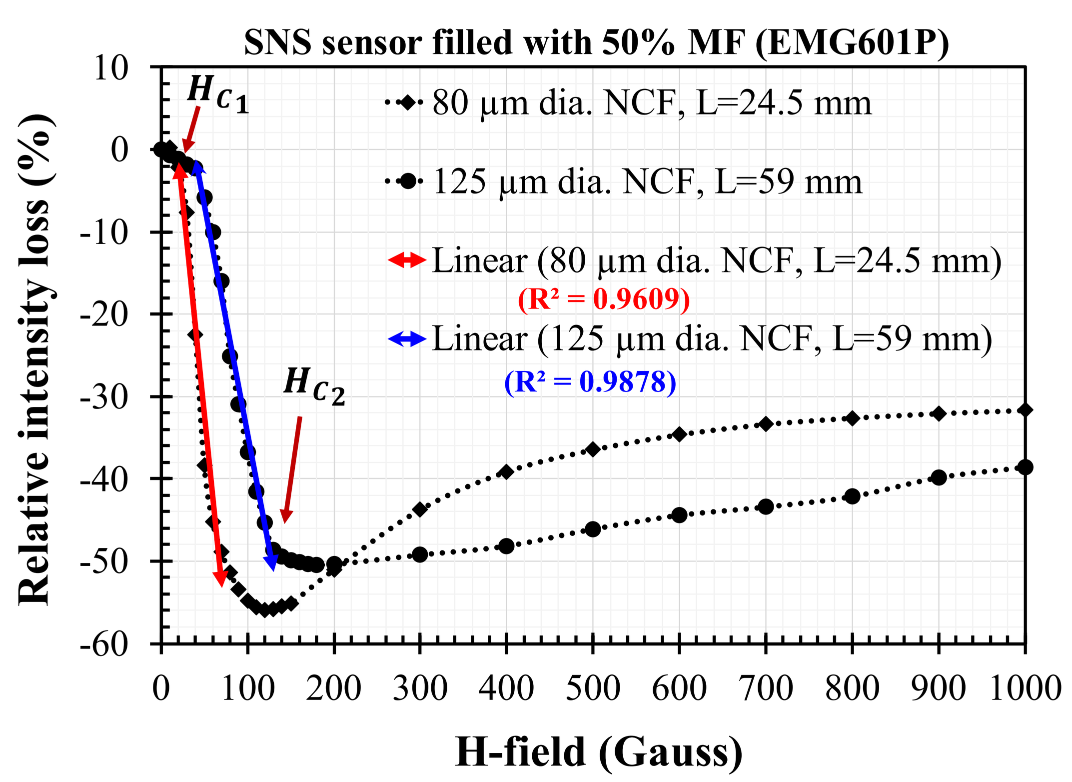
- Sensor optimized for 4th self-imaging peak at C-L band wavelength
- Intensity based interrogation
- Change in relative intensity of 4th self-imaging peak as a function of current induced magnetic field



Results

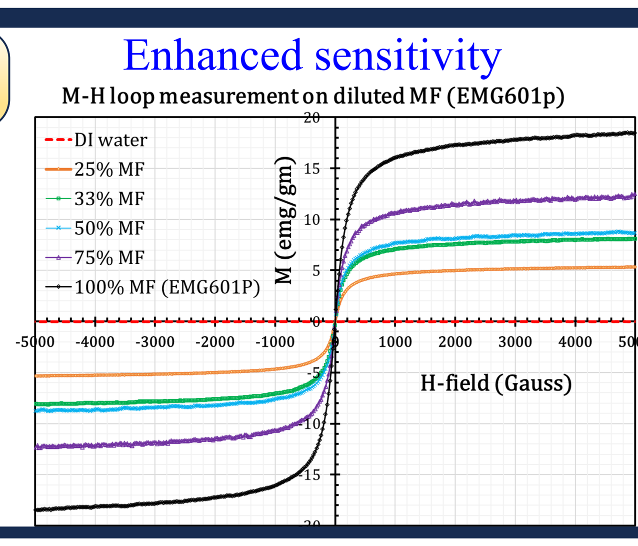
- Sensitivity > 0.5%/Gauss
- Linear response range below 130 Gauss
- Linearity $R^2 > 0.96$

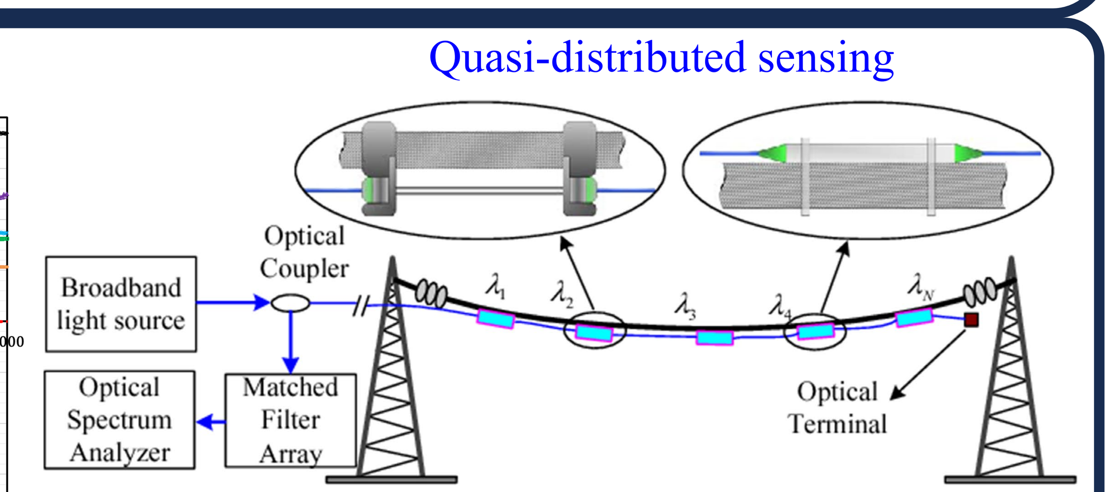
Magnetic fluid-based SMS sensor's performance metrics based on optimized 4th self-imaging condition				
SNS Sensor Specifications	4th self-imaging λ_{peak} (nm)	Response linearity	Sensing range (Gauss)	Sensitivity (S) (% intensity loss/Gauss)
Ø = 125μm, L= 59 mm	1562.64	R^2= 0.9878	40 to 130 Gauss	0.52 %/Gauss
Ø = 80 μm, L= 24.5 mm	1568.28	R^2= 0.9609	10 to 70 Gauss	0.82 %/Gauss



Conclusion and outlook

- DC magnetic field sensing ~200 Amps of equivalent current in a straight wire
- Magnetic fluid with high saturation magnetization and magnetic nanoparticles concentration for higher sensitivity
- Magnetostrictive /magneto-optic materials layers for AC field sensing





Acknowledgement

This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number DE-EE0009632.