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14. ABSTRACT A key aspect of our project is obtaining new ErAs:GaAs epitaxial layers for the development of useful THz extrinsic-photoconductive (PC) devices. To accomplish this a CRADA and purchase order were established with Dr. Rich Mirin at NIST in Boulder, CO. Dr. Mirin did his Ph.D. in the same molecular-beam epitaxy (MBE) group at UC Santa Barbara that developed the useful ErAs:GaAs epitaxial layers in the late 1990s. During the reporting period, Dr. Mirin delivered to Dr. Brown's group at Wright State four ErAs:GaAs epitaxial layers on					
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Report Title

Collaboration with NIST to provide ErAs:GaAs Epitaxial Layers

ABSTRACT

A key aspect of our project is obtaining new ErAs:GaAs epitaxial layers for the development of useful THz extrinsic-photoconductive (PC) devices. To accomplish this a CRADA and purchase order were established with Dr. Rich Mirin at NIST in Boulder, CO. Dr. Mirin did his Ph.D. in the same molecular-beam epitaxy (MBE) group at UC Santa Barbara that developed the useful ErAs:GaAs epitaxial layers in the late 1990s. During the reporting period, Dr. Mirin delivered to Dr. Brown's group at Wright State four ErAs:GaAs epitaxial layers on 3-inch SI-GaAs substrates. The first two were morphologically rough and not amenable to optical testing. The second two were much better and are described in the associated Technical Report. Wright State carried out three important characterizations of these two samples: (1) sheet resistance measurements by the four-point-probe method, (2) VIS-IR measurements of the transmittance around the GaAs band-gap, and (3) ultrafast pump-probe phototransmission measurements with a 1550-nm (EDFA) mode-locked laser. All three provided interesting results, especially the ultrafast pump-probe characterizations which demonstrated ~ 0.33 ps FWHM for each of the two promising samples. The near-term plan is to start fabricating PC switches and photomixers with these samples during October 2013 in the new WSU cleanroom.

Characterization of ErAs-GaAs Epitaxial Layers from NIST

(grown by Dr. Rich Mirin)

M. Martin, J. Owsley, and E.R. Brown
Wright State University
Depts. of Physics and Electrical Engineering

3 Sept. 2013

Four-Point Probe Resistance Measurements

Calculated Sheet Resistivities at Target Locations (A-E) for Samples ASP011 and ASP013

•ASP011

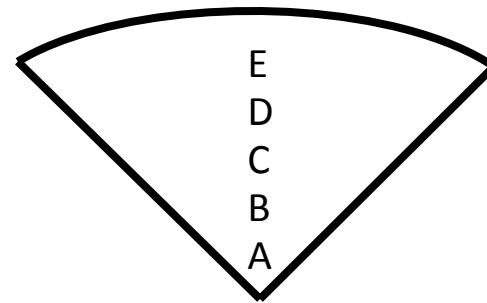
- A= 4.6 Ω -cm
- B=15.5 Ω -cm
- C= 18.21 Ω -cm
- D= 181 Ω -cm
- E= 15.402 *10³ Ω -cm

•ASP013

- A= 2.44 Ω -cm
- B= 2.178 Ω -cm
- C= 15.76 Ω -cm
- D= 18.12 Ω -cm
- E= 160 Ω -cm

Assumption: t = 0.0002 cm

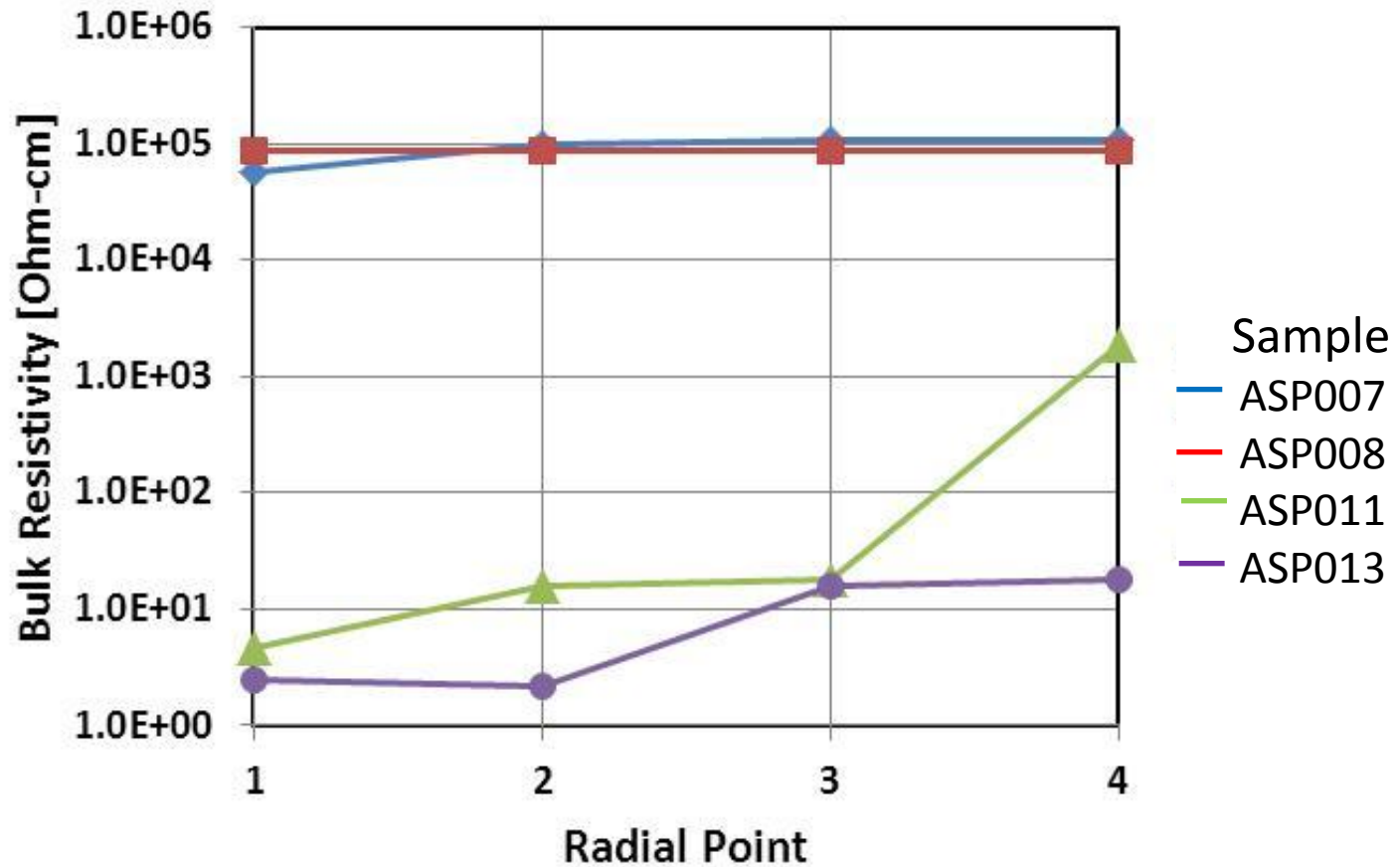
Sample Targets and Sheet Resistivity Equation



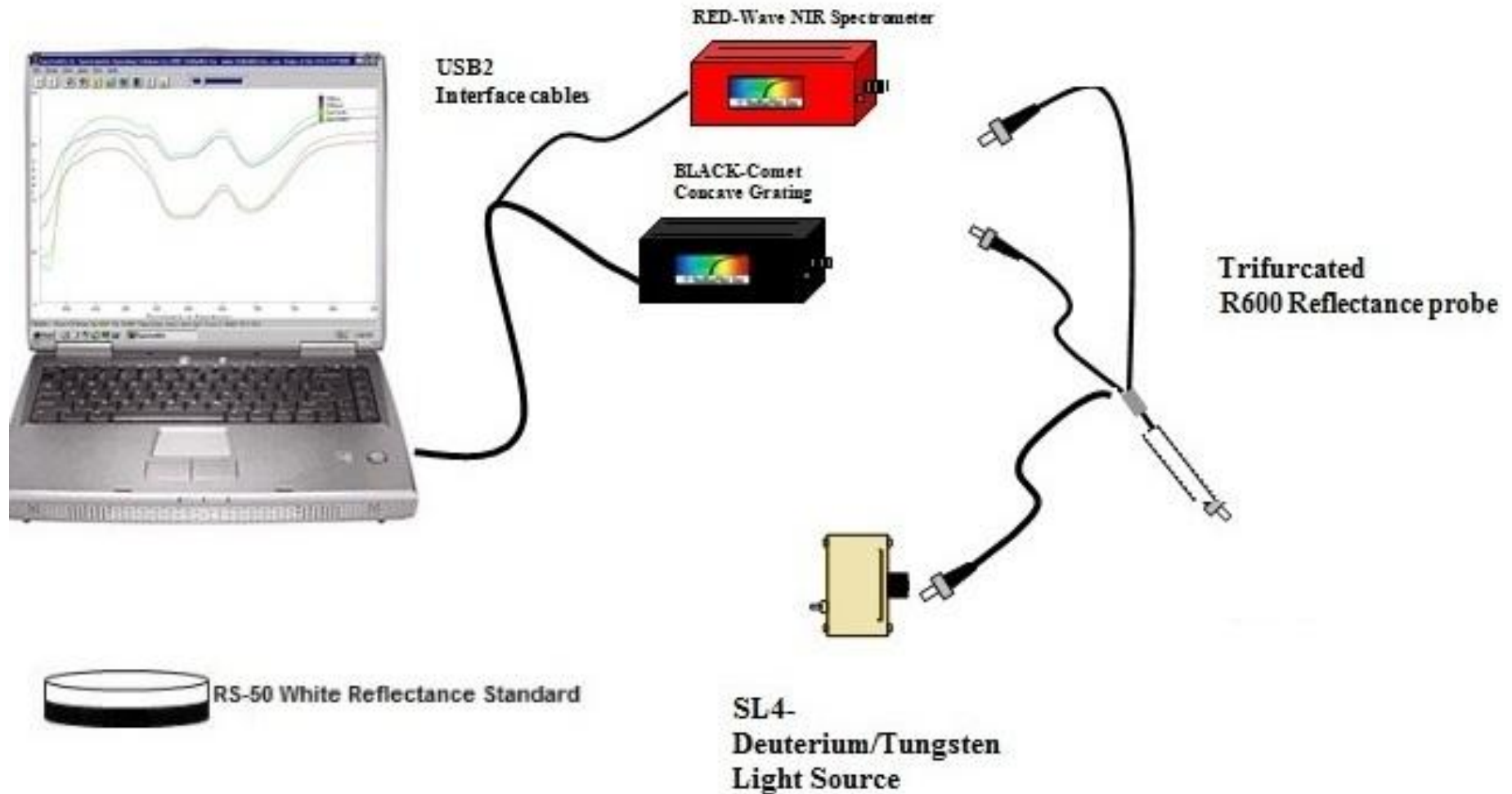
$$\rho_{sheet} = 4.53 * t * \left(\frac{V}{I} \right)$$

Note: Bulk resistivity of semi-insulating GaAs was measured to be 1.17x10⁸ Ω -cm

Four-Point Probe Resistance Measurements

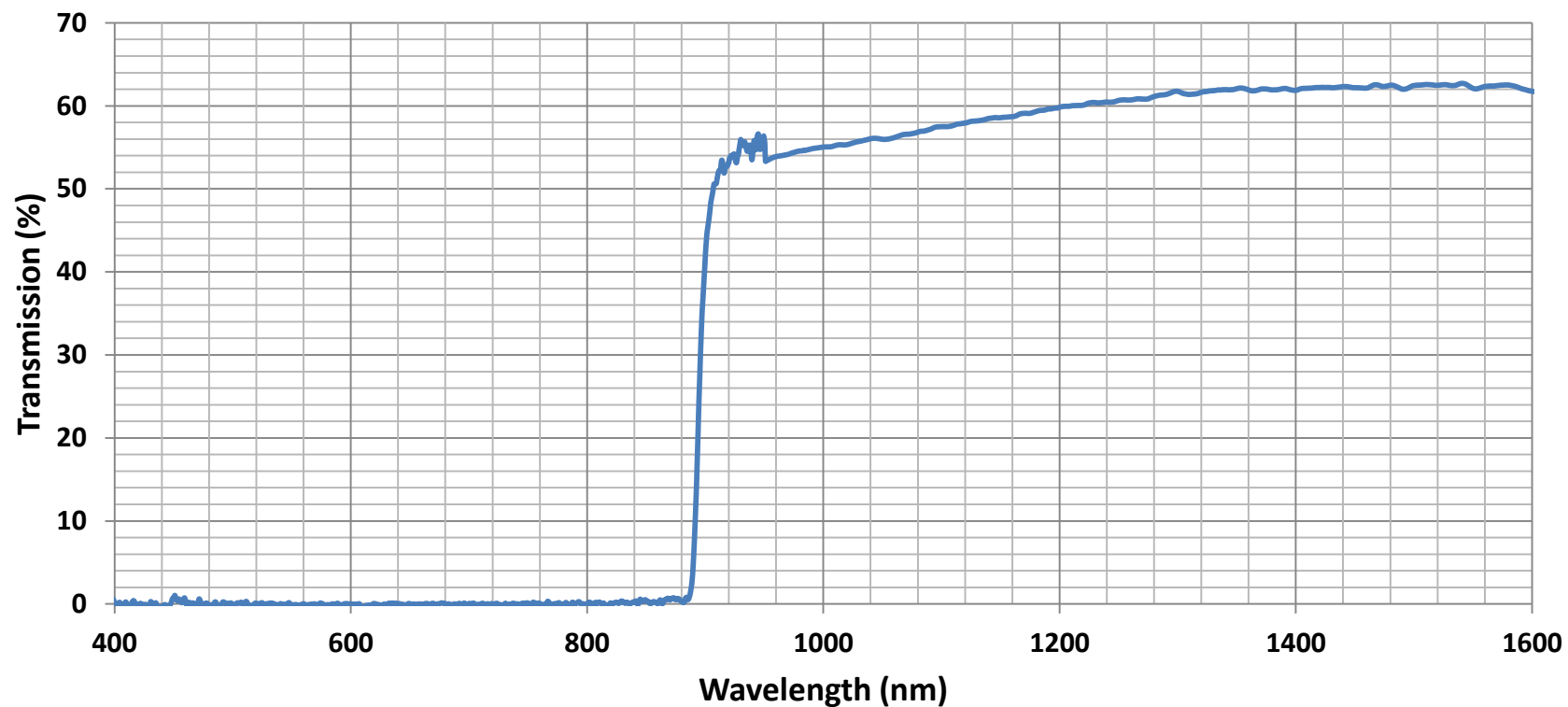


Below-Band-Gap Transmittance Measurements

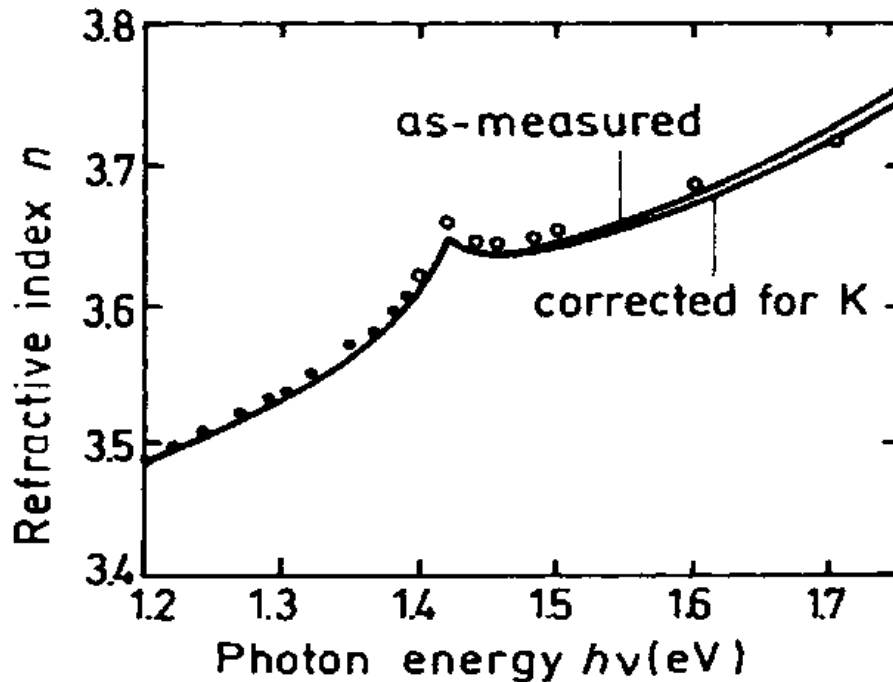


Below-Band-Gap Transmittance Measurements

Double-side Polished SI-GaAs



GaAs Refractive Index and Expected Substrate Transmittance

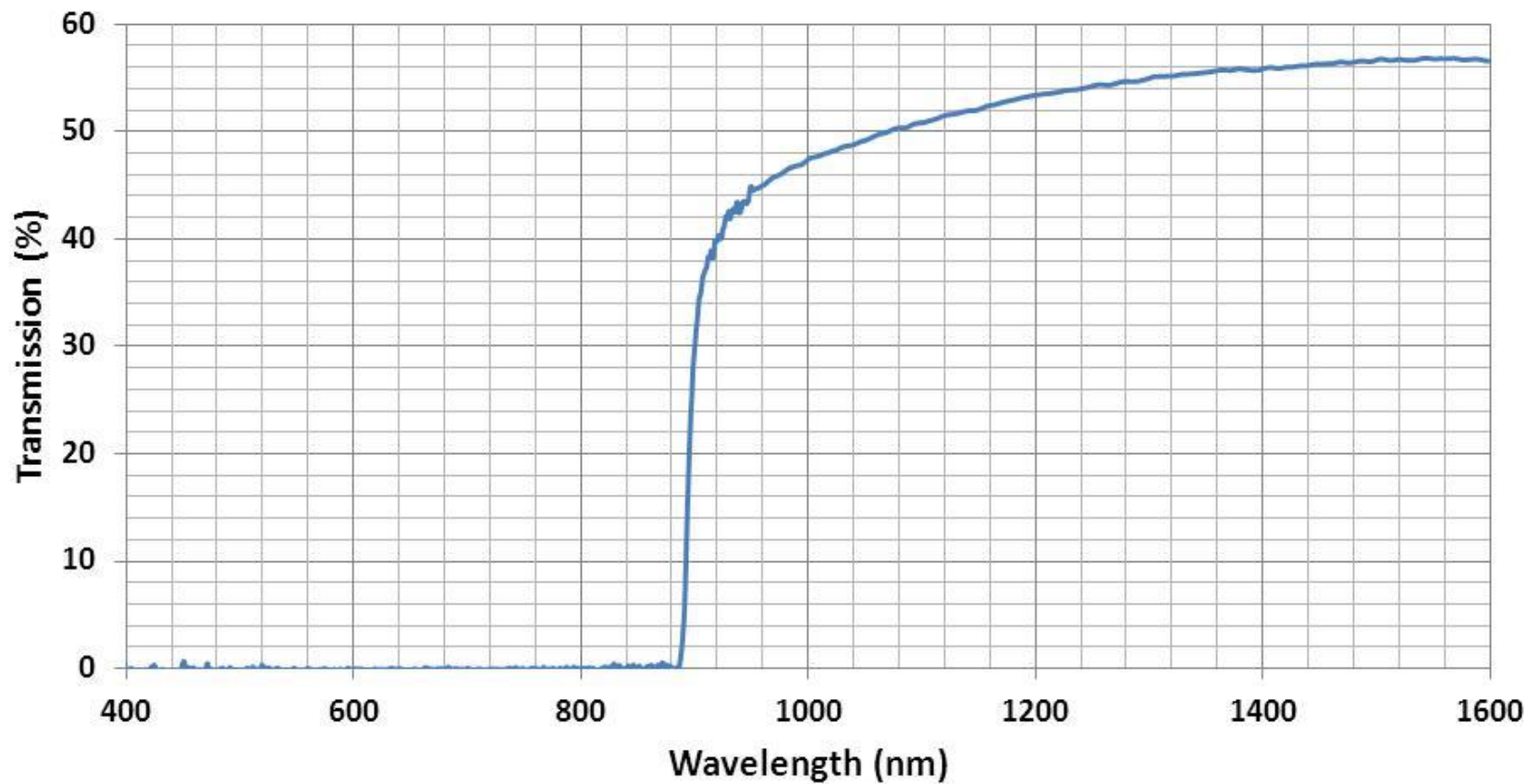


photon energy [eV]	1.2
frequency [Hz]	2.90E+14
wavelength [m]	1.03E-06
refractive index [from Blakemore]	3.48
reflectance	0.31
single-interface transmittance	0.69
two-surface transmittance	0.48

Blakemore, J. S., *J. Appl. Phys.* **53**, 10 (1982) R123-R181.

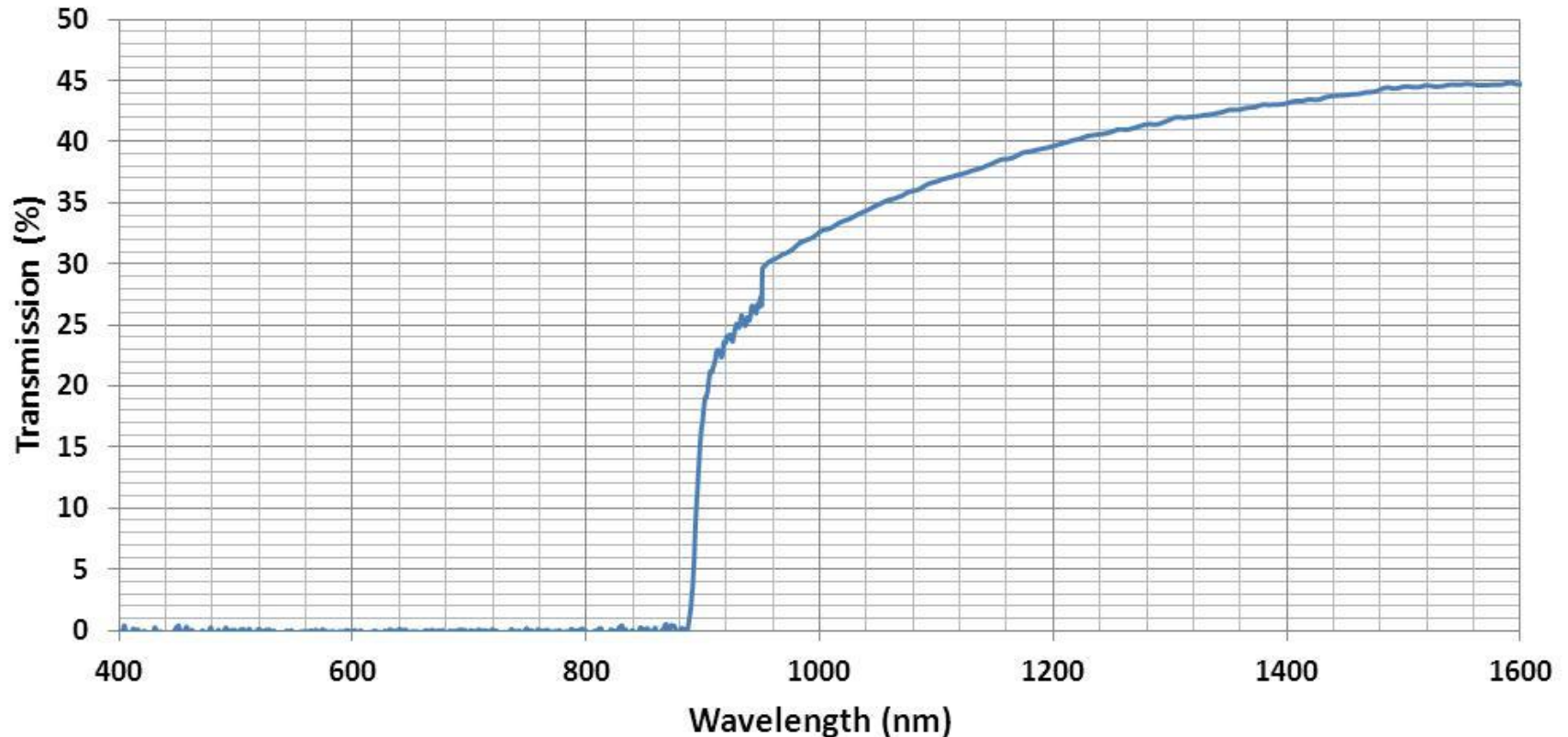
Below-Band-Gap Transmittance Measurements

NIST: ASP011



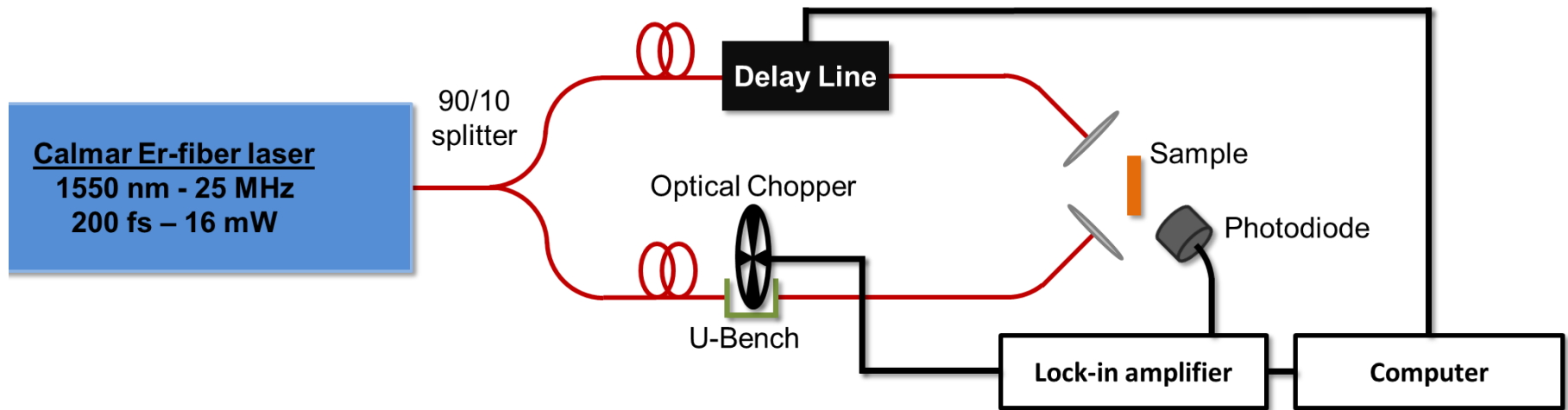
Below-Band-Gap Transmittance Measurements

NIST: ASP013

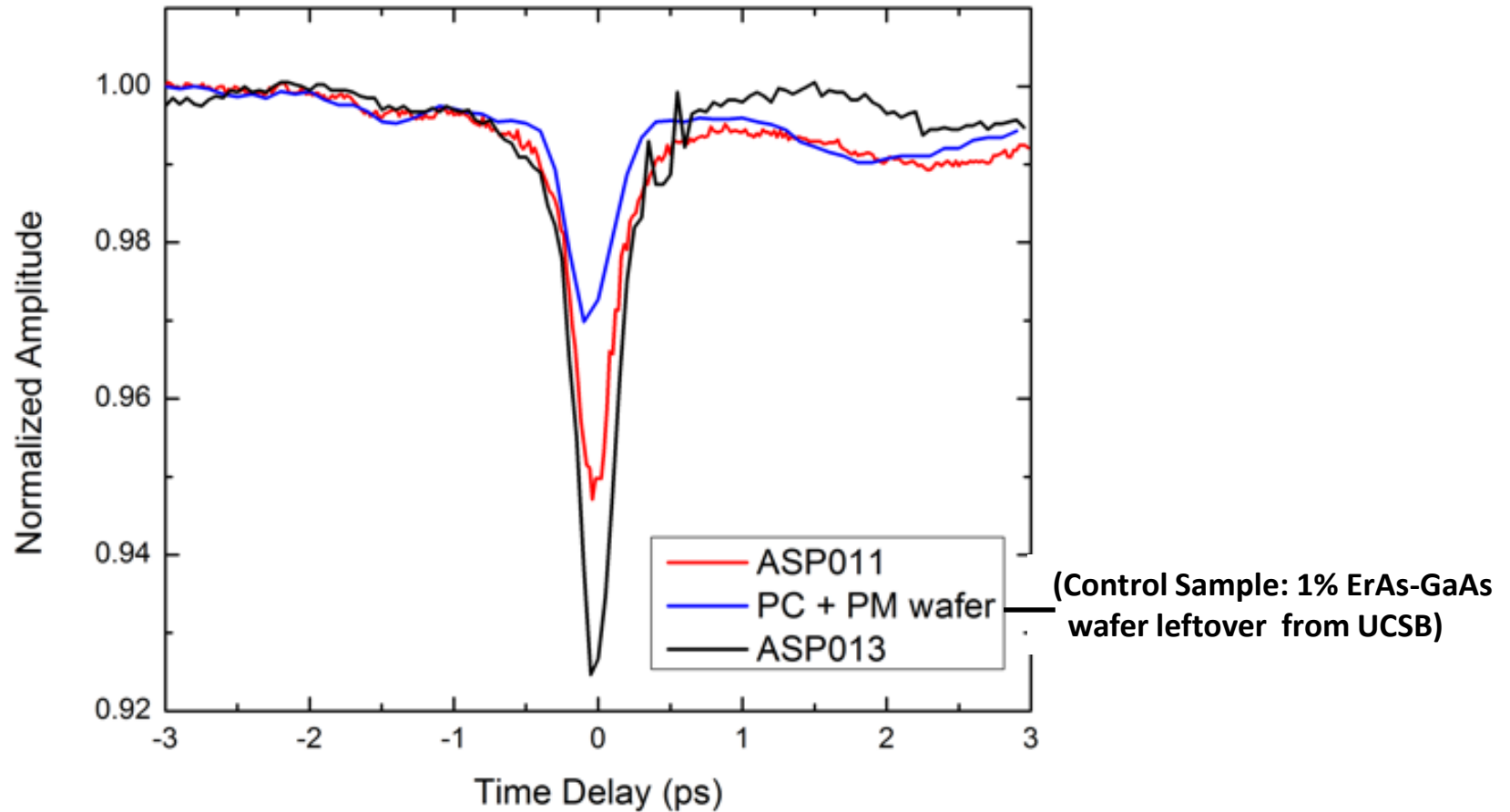


Comment: greater insertion loss of ASP013 compared to ASP011 below band-edge consistent with more surface roughness of ASP013. Discontinuity at ~950 nm caused by splicing of two insrtumental data

1550-nm Ultrafast Pump-Probe Photo-Transmission Set-Up



1550-nm Ultrafast Pump Probe Results



Sample	Width (ps)	Amplitude	Amplitude compared to ErAs:GaAs Control
Control	0.36	0.025445	1.00
ASP011	0.33	0.04417	1.74
ASP013	0.32	0.07165	2.82