Background Spectra and Phonon Peaks:

In this part, background spectrum with laser and without laser is shown as FigureSI-1, FigureSI-2 and FigureSI-3.

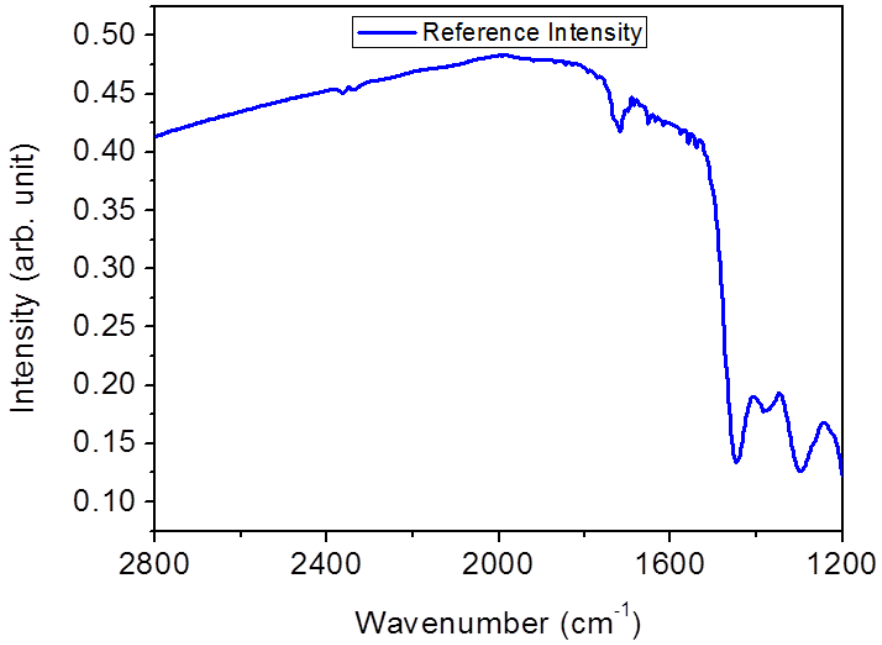

Figure-SI1: Background Spectra

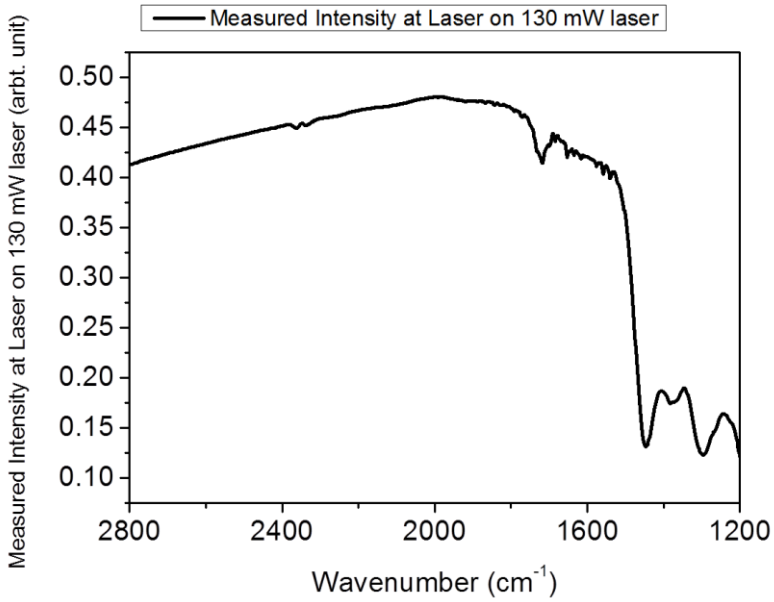

Figure-SI2: Background Spectra

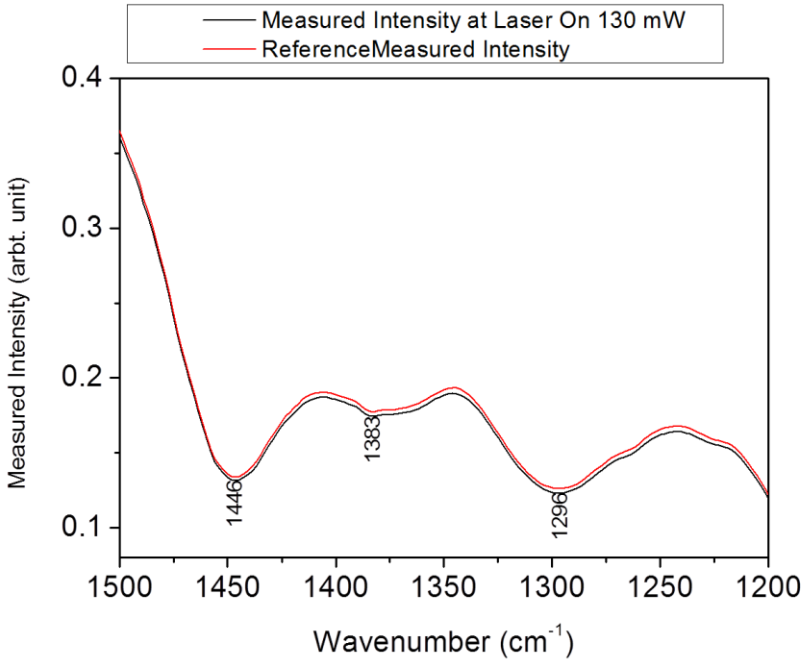

Figure-SI3: Background Spectra and phonon peaks between range 1500cm^{-1} and 1200cm^{-1}

Calculation of Penetration Depth at 1064 nm photon on silicon:

The absorption coeffient (α) for a 1064 nm photon is about[1, 2] 10 cm^{-1}.

Light intensity at any depth can be calculated as follows:

$$I(z) = I_0 \ e^{-\alpha z}$$

Where z is the depth, I(z) is the light intensity at a given depth, I_0 is the initial light intensity.

Penetration depth is defined as the depth at which initial intensity reduces to 1/e (37%).

As a result:

$$100 = 37\ e^{(-\ 10 \times\ z)}$$

From this equation z can be calculated as 0.99 mm.

In addition, our Silicon wafer is 530 µm thick so at the bottom of wafer, the relative intensity can be calculated to amount to58%.

Fitting of Free Carrier Absorption Region:

In order to fit the free carrier absorption to the spectrum, the wavenumber range 1500 cm^{-1} to 2800 cm^{-1} (wavelength range 6.66 µm – 3.57 µm) is selected, because in this region there is no phonon absorption.

The Drude model states that $\alpha = k \lambda^2 N$

We measure Absorbance with our setup and we can relate absorbance as:

$A = L \alpha$

where L is the interaction distance between attenuated total light and laser light.

Finally;

$A = L k \lambda^2 N$

Fitting function of $y = a x^2$ is used, where $a = L k N$

For fitting, The Levenber-Marquart (LMA) error minimization algorithm is used and Fitted functions can be seen in Figure-3 in black.

Some parametes of the fit are shown below for the mentioned interval wavenumber range 1500 cm^{-1} to 2800 cm^{-1} (wavelength range 6.66 µm – 3.57 µm)

Fitted Curve: $y = a \lambda^2$ (a refers to L k N (cm^{-2}) in the Drude model)

Illumination Power (mW)	L k N (cm^{-2})	Standard Error	Adj. R-Square
50	5.05142×10^{-5}	2.35432×10^{-7}	0.9095
90	9.22127×10^{-5}	4.34271×10^{-7}	0.92127
130	1.88363×10^{-4}	3.94204×10^{-7}	0.97444

Calculating Phonon Absorption:

The phonon absorption peaks are seen in FigureSI-4 These spectra are obtained by subtracting free carrier absorption plots (shown as black in Figure-2 from experimental data in Figure-2. After that, background correction is performed.

Figure SI-4: Phonon Absorption peaks

1. M. A. Green and M. J. Keevers, *Prog Photovoltaics*, 1995, **3**, 189-192.
2. R. Schnabel, M. Britzger, F. Bruckner, O. Burmeister, K. Danzmann, J. Duck, T. Eberle, D. Friedrich, H. Luck, M. Mehmet, R. Nawrodt, S. Steinlechner and B. Willke, in *8th Edoardo Amaldi Conference on Gravitational Waves*, eds. Z. Marka and S. Marka, Iop Publishing Ltd, Bristol, 2010, vol. 228.