Supporting information

Extraordinary Photoresponse in Two-Dimensional In_2Se_3 Nanosheets

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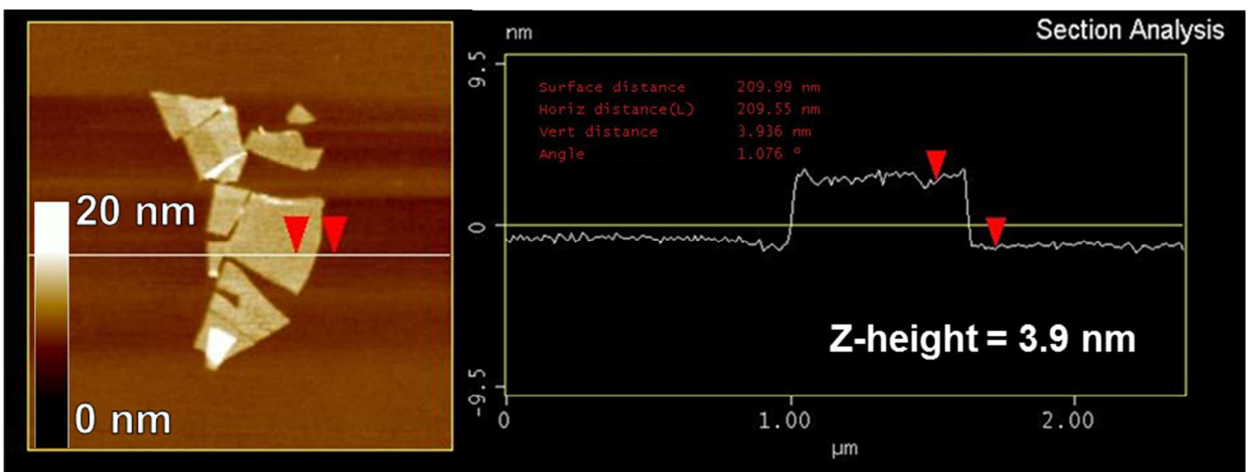

Figure S1: AFM image given in manuscript Figure 1B with corresponding line scan which was used to determine the thickness of the nanosheet. The difference in Z-height between the two points of the line scan indicated with red arrows is equal to 3.93 nanometers.

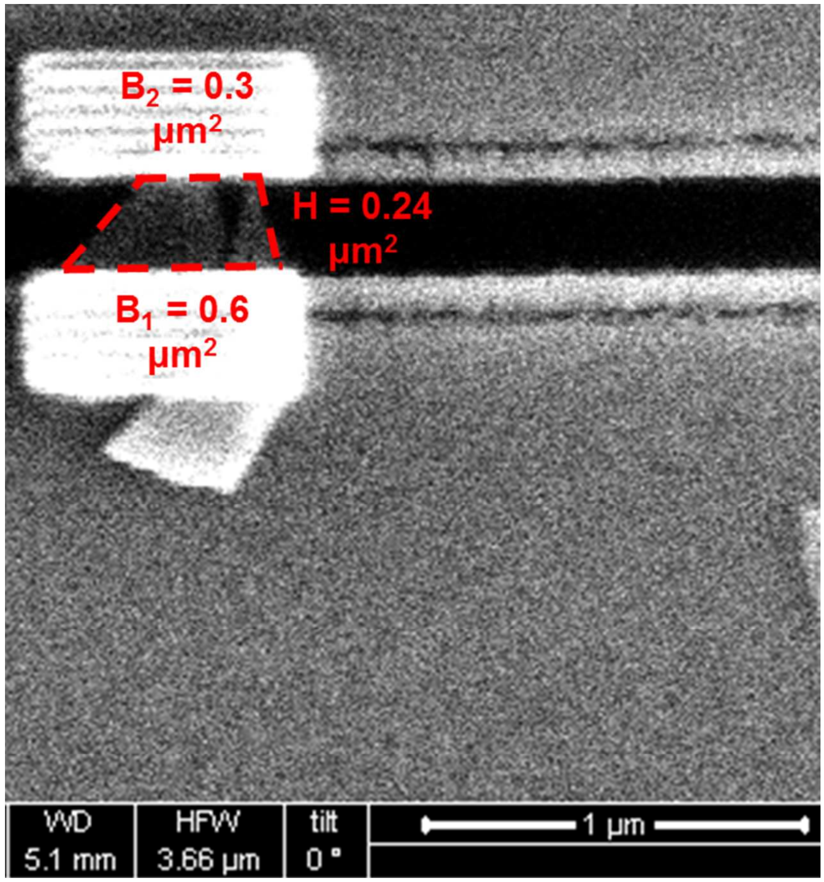

Figure S2: SEM image from Figure 3B with the active channel area outlined in red. The active channel area was calculated by using the equation for the area of a trapezoid ($A = \frac{(B_1+B_2)H}{2}$). The measured active area is A = 0.108 µm^2. The original scale bar from the micrograph is included for reference.

Calculation of Responsivity:

The calculation of responsivity at 300 nm and 5 V as discussed in the manuscript is given as an example below:

DET25K Area: $A_1 = 4.80 \cdot 10^{6}$ m^2
DET25K Responsivity @ 300 nm: $R_{\lambda 1} = 6.00 \cdot 10^{-2}$ A/W
DET25K Photocurrent: $I_{\lambda 1} = 1.35 \cdot 10^{-07}$A
Applying $P_\lambda = \frac{I_{\lambda 1}}{R_{\lambda 1} A}$ results in a light power density of $P_\lambda = 4.69 \cdot 10^{-1}$ W/m^2.

In_2Se_3 Photodetector Area: $A_2 = 0.108$ µm^2
In_2Se_3 Bright Current: $I_{\lambda 2} = 5.12 \cdot 10^{-12}$ A

Using the light power density measured with the DET25K data (above) and applying $R_{\lambda 2} = \frac{I_{\lambda 2}}{P_\lambda A_2}$ we obtain the measured responsivity of $R_{\lambda 2} = 3.95 \cdot 10^{2}$ A/W^{-1}.

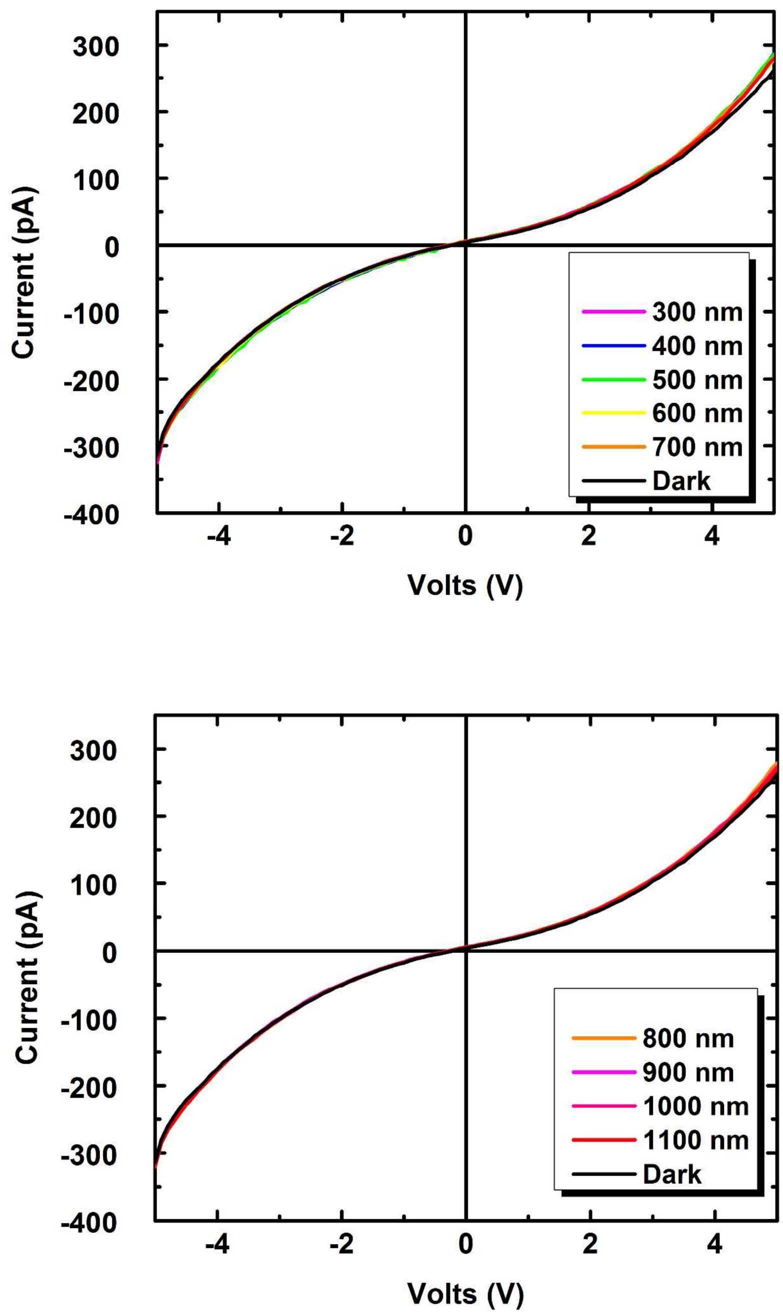

Figure S3: Full sweep from -5 V to + 5 V of the photocurrent I-V measurement as shown in Figures 5(A) and 5(B) in the manuscript.

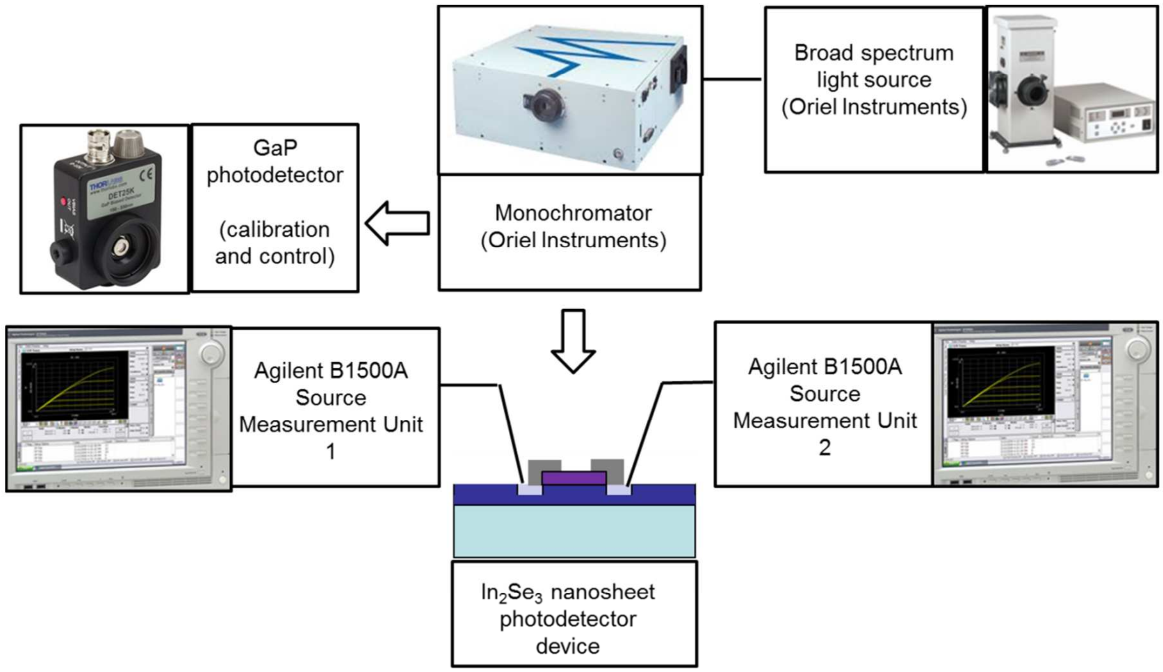

Figure S4: Experimental setup used to measure responsivity, external quantum efficiency, and specific detectivity. The spectral irradiance was 1.56 $mW{\cdot}m^{-2}{\cdot}nm^{-1}$ at 300 nm, 5.21 $mW{\cdot}m^{-2}{\cdot}nm^{-1}$ at 400 nm, and 7.22 $mW{\cdot}m^{-2}{\cdot}nm^{-1}$ at 500 nm. The results are consistent with the specified irradiance of the Oriel instruments 7258 arc lamp and efficiency of the Oriel 600I/mm diffraction grating.

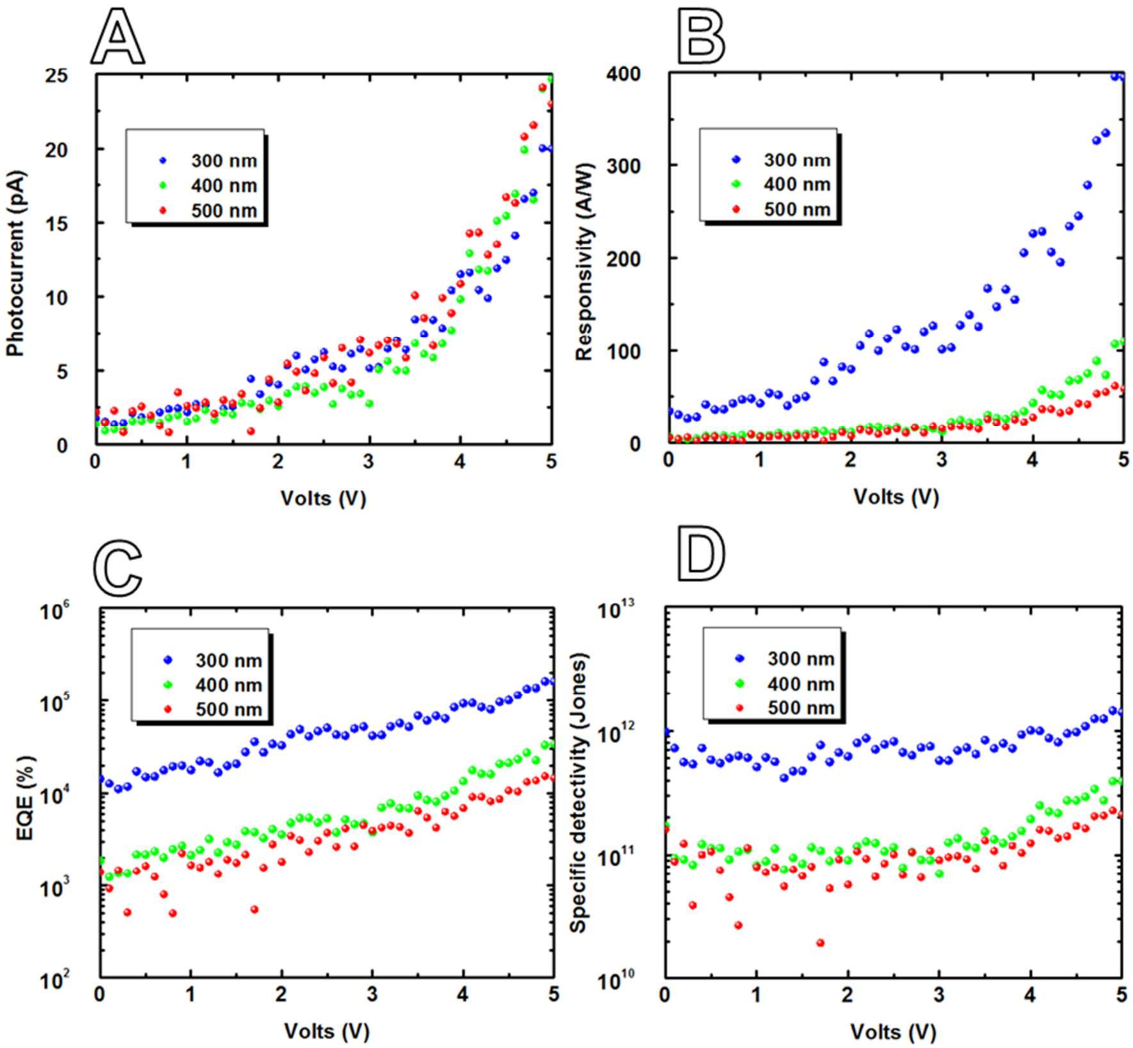

Figure S5: Measured wavelength-dependant key device metrics: **(A)** photocurrent, **(B)** responsivity, **(C)** EQE, and **(D)** specific detectivity with respect to electrical biasing for the In_2Se_3 nanosheet reported in the manuscript.

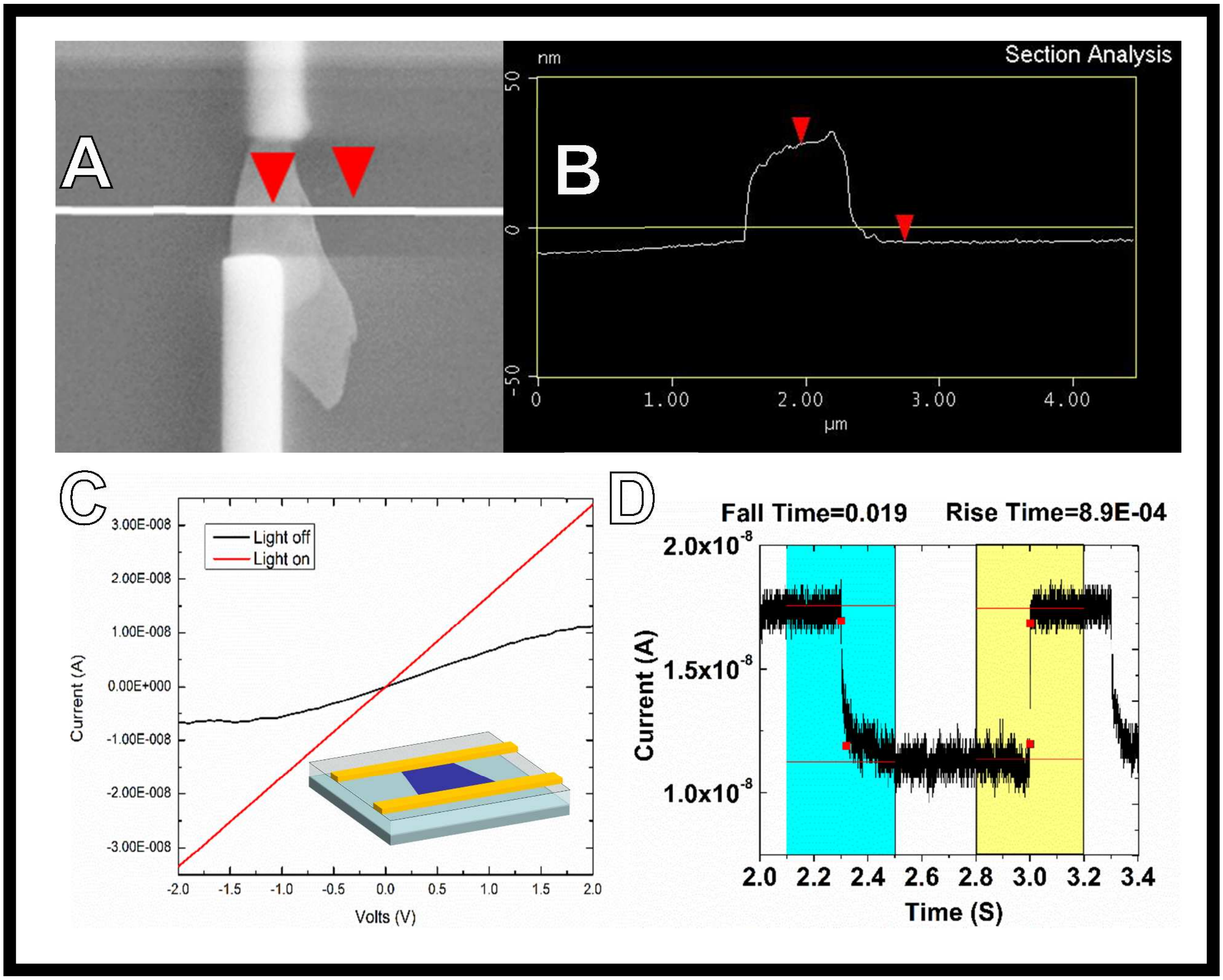

Figure S6: (A) SEM image of an In_2Se_3 nanosheet photodetector with the area of AFM line-scan shown. Contacts are FIB-deposited Pt / amorphous carbon. **(B)** AFM line-scan indicating that the approximate Z-height of the nanosheet is 33 nm. **(C)** Photocurrent response of the detector to a broad spectrum light source (with reference to the dark current). **(D)** Single-cycle response characteristics of the photodetector for rise / fall time analysis.

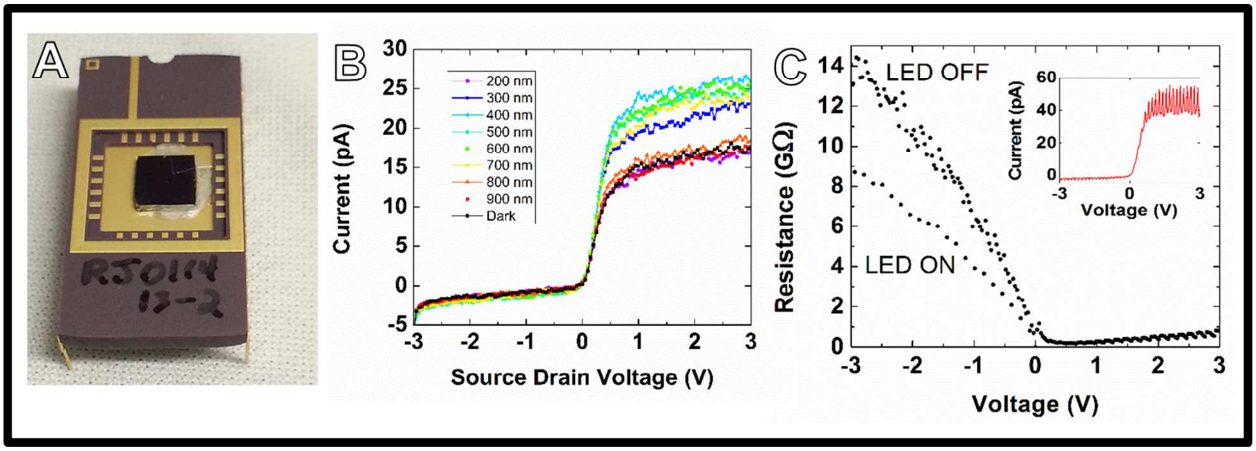

Figure S7: (A) Image of the packaged device in Figure S5 after packaging and wire-bonding. **(B)** Photocurrent response of the device (after wire-bonding and packaging) under exposure to the monochromatic light source. Dark current I-V demonstrates diode characteristics not present in device before wire-bonding step. **(C)** Photocurrent response of the packaged device to the green LED pulsed on/off at a frequency of 10 Hz.

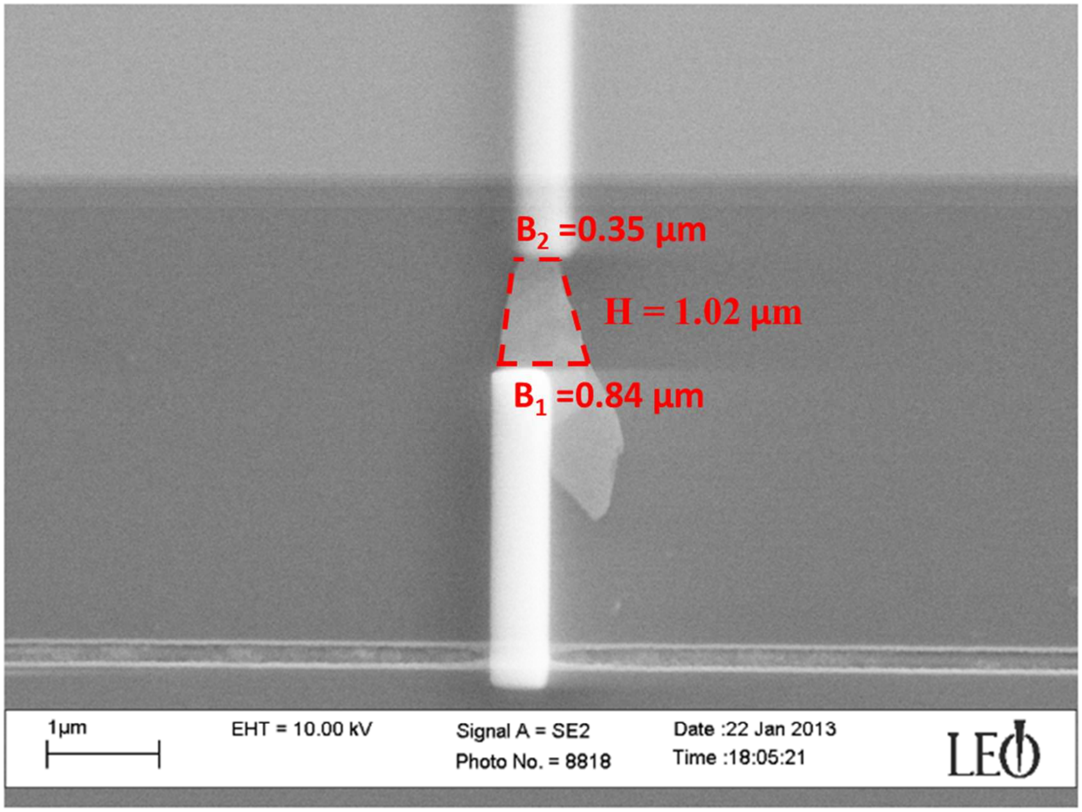

Figure S8: SEM image of the nanosheet device with active channel area outlined in red. The active channel is the area between the contacts where electrical bias is applied. Active channel area was measured to be 1.22 µm^2.

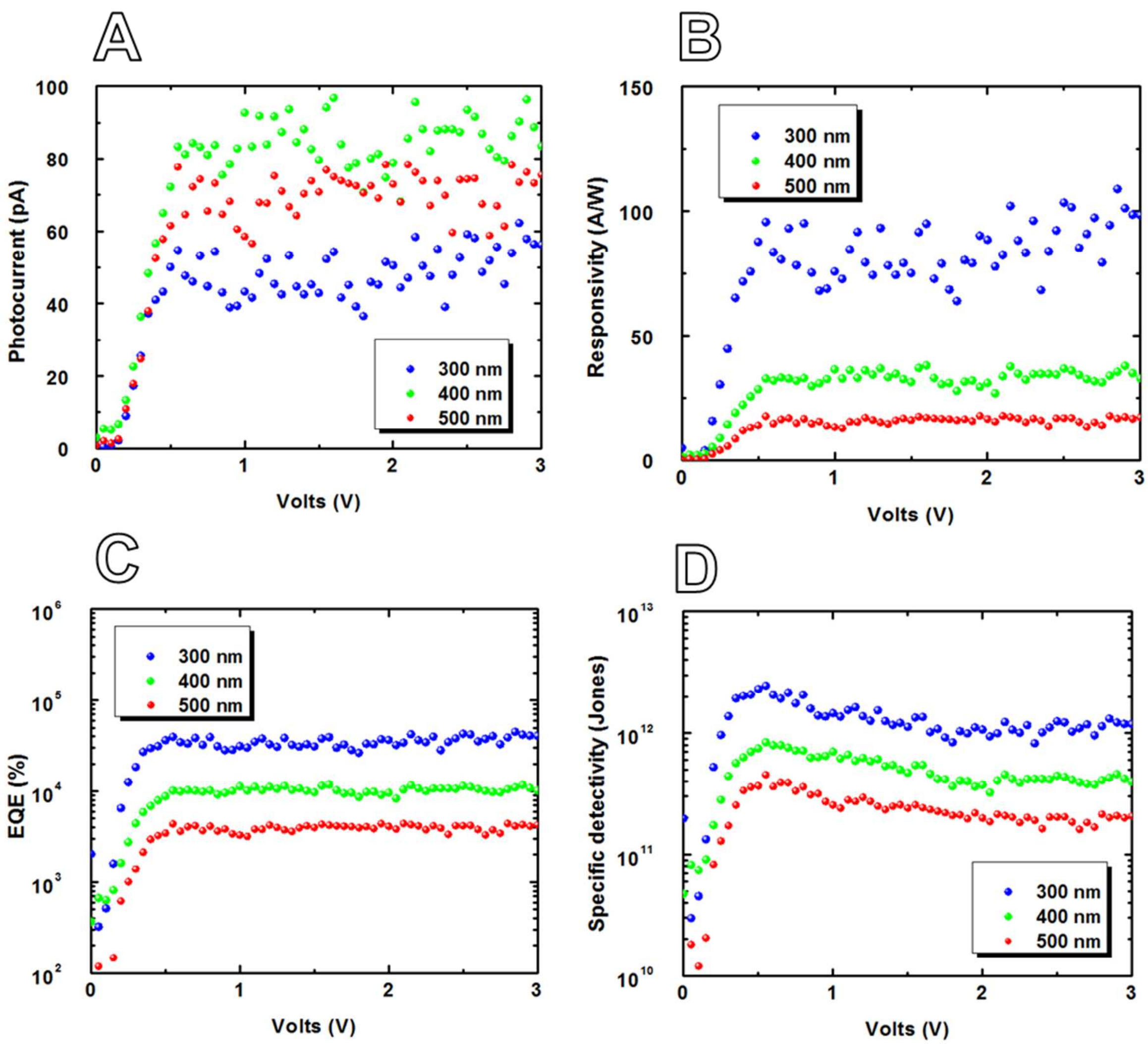

Figure S9: Measured wavelength-dependant key device metrics: **(A)** photocurrent, **(B)** responsivity, **(C)** EQE, and **(D)** specific detectivity with respect to electrical biasing for the In_2Se_3 nanosheet as shown in Figures S6, S7, and S8.

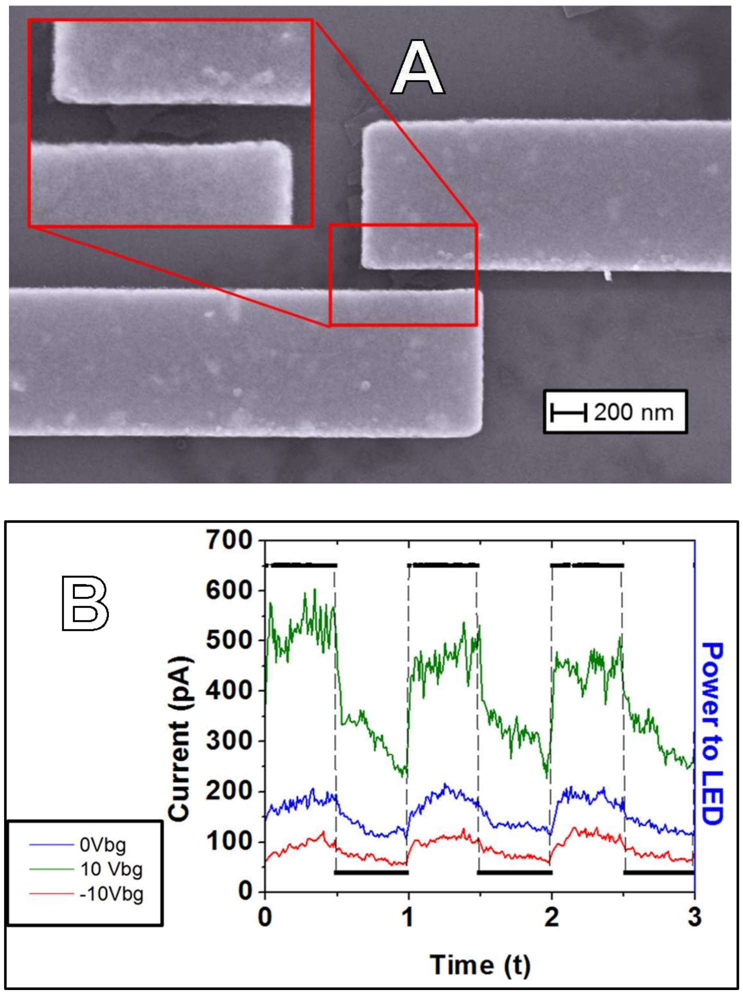

Figure S10: (A) In_2Se_3 nanosheet device on 5 nm HfO_2 / 300 nm SiO_2 / Si substrate with 5 nm Ti / 40 nm Au contacts fabricated by electron-beam evaporation and subsequent electron-beam lithography. The nanosheet is the same as shown in Figure 1(A), (B) and S1. Under the excitation of green LED pulsed at 1 Hz, an increase in photoconduction is observed with a positive 10 V backgate bias. Alternatively, photoconduction can be suppressed by applying a negative gate bias.