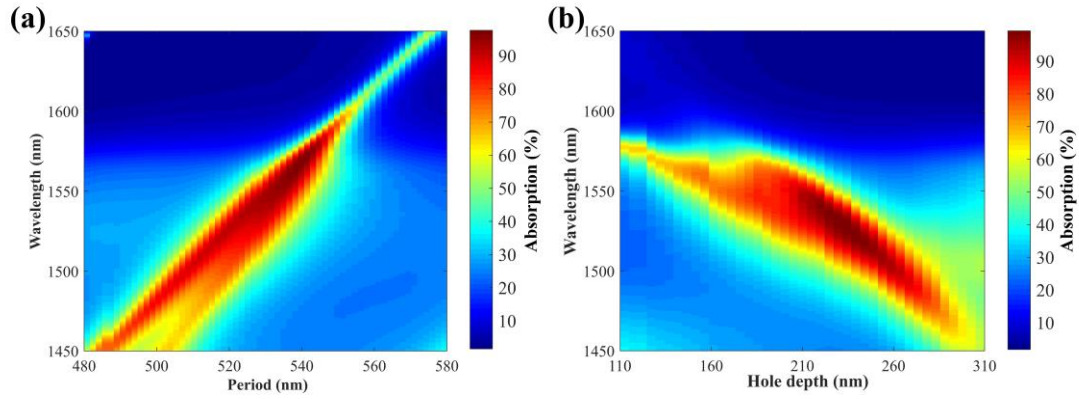
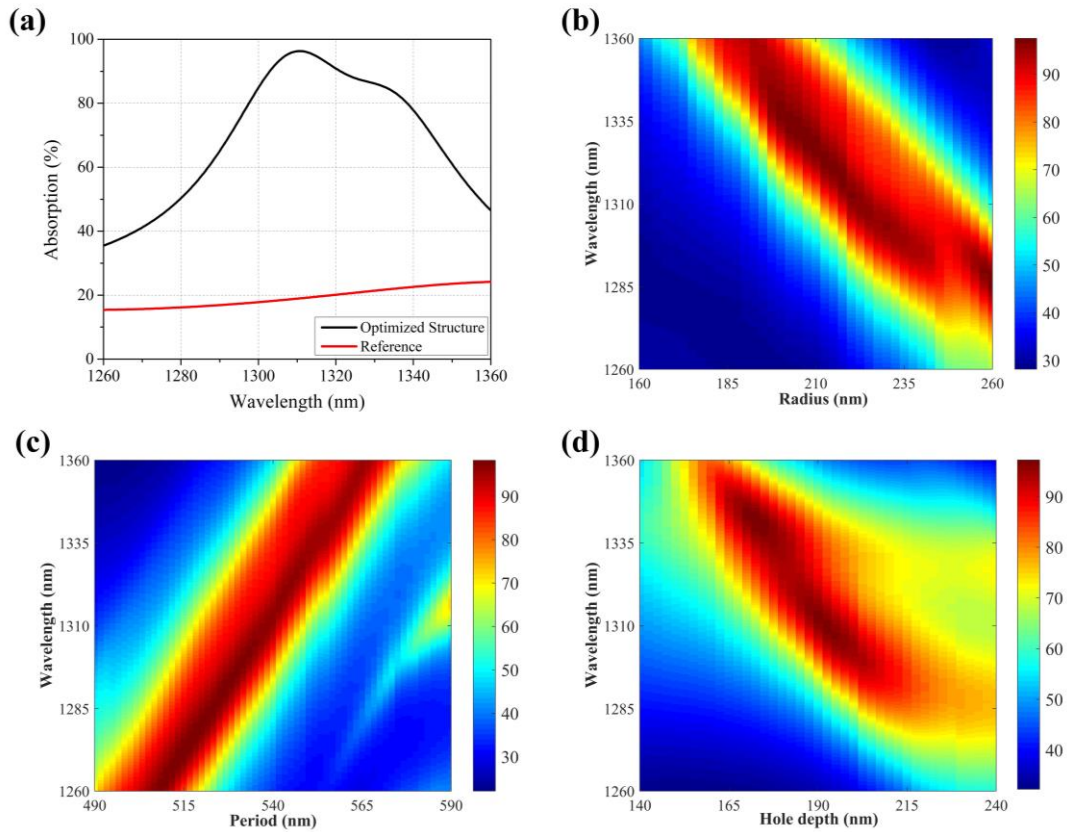


## SI. The absorption spectrum of the hole array as functions of their period and depth.



**Figure S1.** Calculated absorption spectrum of the hole array as functions of hole period (a) and hole depth (b). The basic parameters of the hole array are: period = 530 nm, hole radius = 220 nm, hole depth = 210 nm.

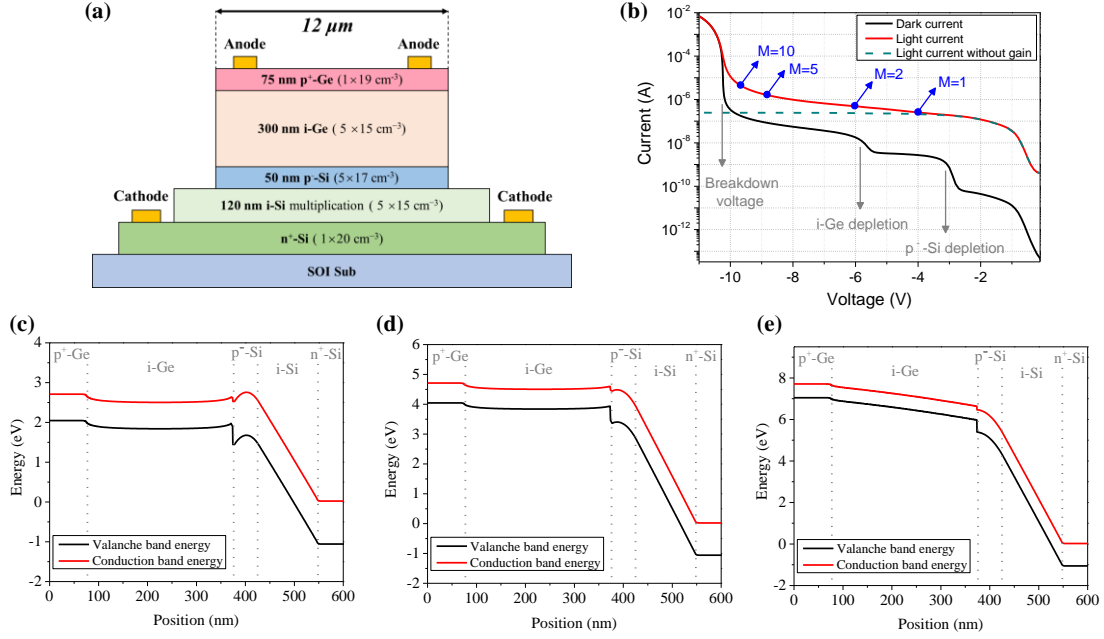
## SII. Design of hole array for absorption enhancement at 1310 nm.



**Figure S2.** (a) Calculated absorption spectra of the optimized hole array and the reference structure without hole array. Calculated absorption spectrum of the hole array as functions of hole radius (b), period (c) and hole depth (d).

The basic parameters of the hole array are: period = 540 nm, hole radius = 220 nm, hole depth = 190 nm.

### SIII. The current-voltage property of the SACM APD with a 12- $\mu\text{m}$ -diameter top mesa.



**Figure S3.** (a) The structure diagram of the SACM APD with a 12- $\mu\text{m}$ -diameter top mesa. (b) The current-voltage curve of the APD. The green dash line shows the current-voltage curve of the APD with no gain on illumination. (c-e) The energy band diagram of the APD under different bias voltage. (c) The bias voltage is -2 V. (d) The bias voltage is -4 V. (f) The bias voltage is -7 V.

The Shockley-Read-Hall Recombination, Parallel Electric Field Dependence and Selberherr's Impact Ionization models are used in Atlas to simulate the current-voltage property of the APD. To calculate the light current at unit gain ( $M=1$ ) in Figure S3(b), the current-voltage of the APD under illumination is simulated by Atlas without using Impact Ionization model, as shown as the green dash line. By comparison, the light current at a bias voltage of -4 V equals the value expected at  $M=1$ . It should be noted that the  $\text{i-Ge}$  layer is not yet fully depleted at -4 V, as shown as Figure S3(d). The generated photocurrent of the  $\text{i-Ge}$  layer is only partially collected, with the lost portion compensated by the gain of the  $\text{i-Si}$  layer. Based on the light current at -4 V, the bias voltages with gain values of 2, 5, and 10 are determined to be -6.2 V, -8.9 V, and -9.7 V, respectively.