Calculating short circuit current density \((J_{sc})\) from external quantum efficiency (EQE)

External quantum efficiency (EQE) is defined as the ratio of number of charge carriers collected at the electrode to the number of photons incident on the solar cell. EQE is expressed as:

\[
EQE(\lambda) = \frac{\text{number of electrons collected}}{\text{number of photons incident}} = \frac{N_e(\lambda)}{N_{ph}(\lambda)}
\]

\[
EQE(\lambda) = \frac{\frac{N_e}{\Delta t \cdot A}}{\frac{N_{ph}}{\Delta t \cdot A}} = \frac{\text{electron flux}}{\text{photon flux}}
\]

Where, \(\Delta t\) is time duration and \(A\) is area

Volume current density \((J_{sc})\) = (electron flux) \(*\) (charge of electron)

\[
J_{sc}(\lambda) = \frac{N_e q}{\Delta t \cdot A}
\]

\[
EQE(\lambda) = \frac{\frac{N_e q}{\Delta t \cdot A} \cdot \frac{1}{q}}{\frac{N_{ph}}{\Delta t \cdot A}} = \frac{J_{sc}(\lambda)}{\frac{q}{N_{ph}}}
\]

\[
\left(\frac{N_{ph}}{\Delta t \cdot A}\right) \times h\nu = \frac{N_{ph}}{\Delta t \cdot A} \times \frac{hc}{\lambda} = P_0(\lambda)
\]

Where, \(\frac{hc}{\lambda}\) is energy of photon at corresponding wavelength and \(P_0(\lambda)\) is energy of photon having wavelength \((\lambda)\) per unit area per unit time.

\[
EQE(\lambda) = \frac{J_{sc}(\lambda)}{q} \left(\frac{N_{ph}}{\Delta t \cdot A} \times \frac{hc}{\lambda} \right) = \frac{J_{sc}(\lambda)}{P_0(\lambda) \frac{\lambda}{hc}}
\]
\[ J_{SC}(\lambda) = q \cdot EQE(\lambda) \frac{P_0}{hc/\lambda} \]

The AM1.5G spectra is available in the form of energy of photon per unit area per unit time per unit wavelength as shown in figure 1.

Therefore if \( P_0 \) is replaced by AM1.5G data, \( J_{SC} \) should be written in the following form.

\[ J_{SC}(\lambda) = qEQE(\lambda) \frac{P_0/\lambda}{hc/\lambda} \]

For a small range of wavelength, the expression would be

\[ dJ_{SC}(\lambda) = qEQE(\lambda) \frac{P_0/\lambda}{hc/\lambda} d\lambda \]

By integrating the expression over a wavelength range \( \lambda_1 \) to \( \lambda_2 \), \( J_{sc} \) can be obtained.

\[ J_{sc} = q \int_{\lambda_1}^{\lambda_2} EQE(\lambda) \frac{P_0(\lambda)}{hc/\lambda} d\lambda = q \int_{\lambda_1}^{\lambda_2} EQE(\lambda) \frac{AM1.5G}{hc/\lambda} d\lambda \]

Where, \( \phi_{ph,\lambda}^{AM1.5G} = \frac{AM1.5G(\lambda)}{hc/\lambda} \)