



**Figure 14.12** Local variations in quantum efficiency with 1- $\mu\text{m}$  beam and  $\lambda = 788$  nm. Areas shown are  $50 \times 10 \mu\text{m}$

overall and exhibits a peak near the CdTe band edge, suggesting *p-i-n* device operation [137]. With either air treatment or vapor  $\text{CdCl}_2$  + air treatment, the  $J-V$  and spectral response behavior correspond to *p-n* device operation, with optimal properties obtained for the vapor  $\text{CdCl}_2$  + air treatment. For devices made by other methods, similar behavior is obtained, but the starting condition (Figure 14.11a) can be improved by deposition at high temperature in an oxygen-containing ambient.

The effect of the  $\text{CdCl}_2$  treatment on photocurrent microuniformity is shown in Figure 14.12, for cells with CdTe deposited by CSS. The QE map on the left was made on a cell following a typical  $\text{CdCl}_2$  treatment, and shows spatially uniform collection. The map on the right was for a cell fabricated without the  $\text{CdCl}_2$  treatment and exhibits considerable nonuniformity [138]. The light intensity for these maps is nearly  $100 \text{ mW/cm}^2$  and the light spot is slightly smaller than  $1 \mu\text{m}$ . The large local reductions in photocurrent without  $\text{CdCl}_2$  treatment are areas of high resistance associated with grain boundaries. With the use of the  $\text{CdCl}_2$  treatment, spatial-junction uniformity is improved by the electronic incorporation of Cl and O species and alloy formation by diffusion of CdS into CdTe. The QE of the sample with  $\text{CdCl}_2$  treatment is  $\sim 0.82$  over 95% of the measured area, while that of the sample without  $\text{CdCl}_2$  treatment ranges from 0.50 to 0.68.

### 14.3.3 CdS/CdTe Intermixing

All CdS/CdTe cells are exposed to processing temperatures of at least  $350^\circ\text{C}$  during  $\text{CdCl}_2$  treatment. In some cases, such as spray pyrolysis, much higher temperatures are involved. Hence, a chemical reaction between CdTe and CdS can occur and this is the