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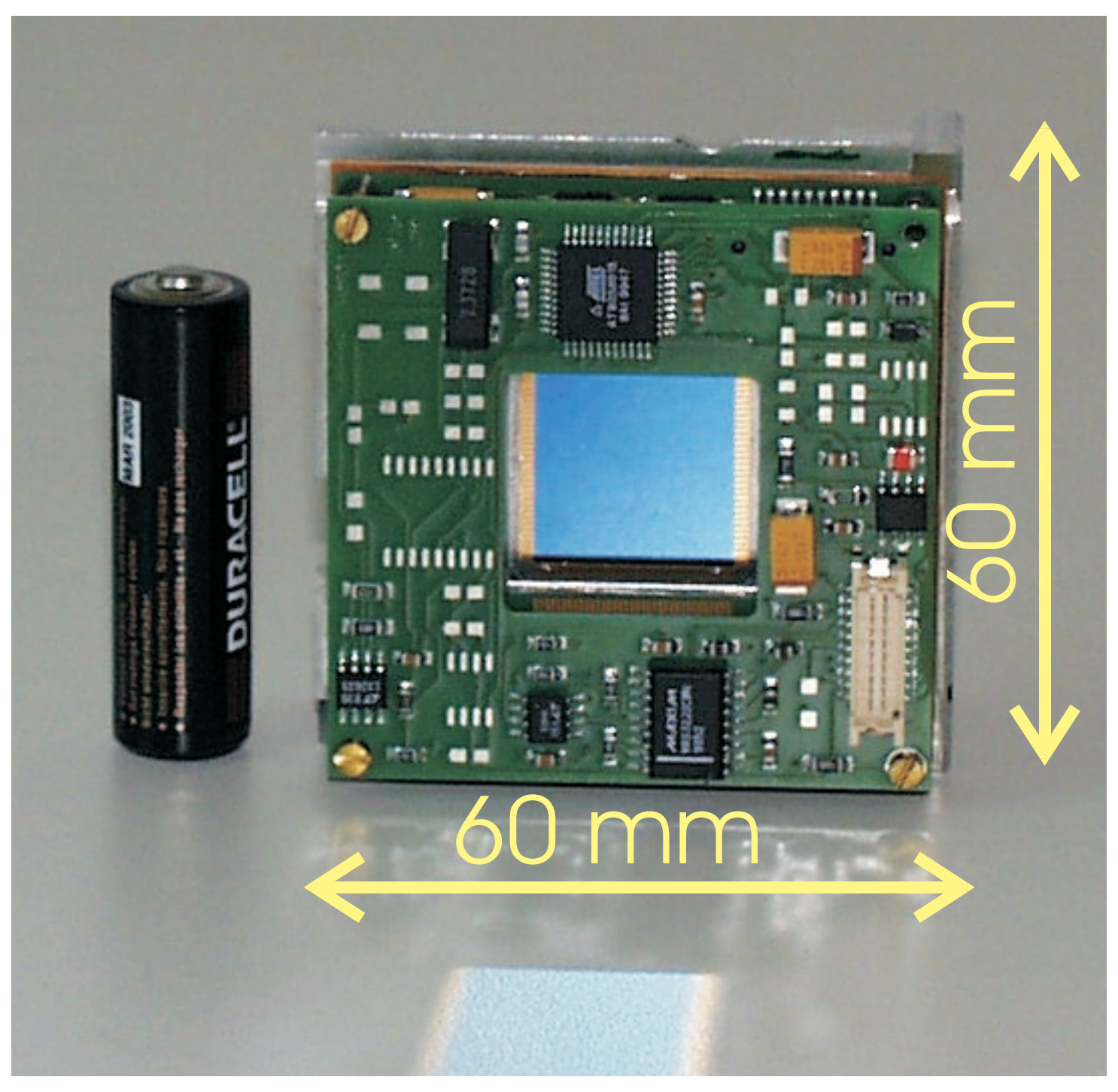
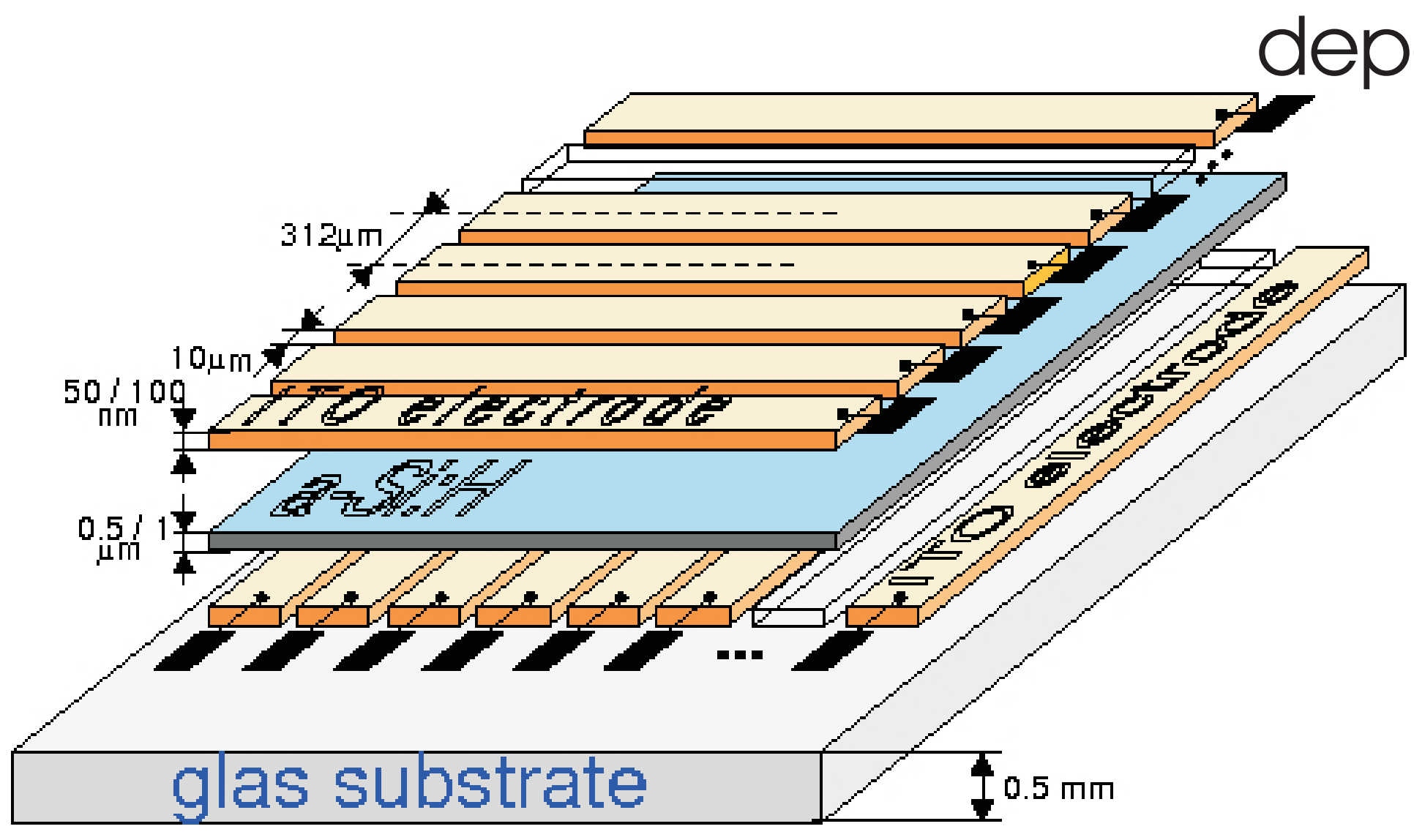
Long-term behaviour of the sensitivity of amorphous silicon photo detectors

Abstract We study the deterioration of the photo current response of the hydrogenated amorphous silicon (a-Si:H) under illumination.
The position sensitivity of a-Si:H detectors allows for the significant reduction of systematic measurement errors originating from the varying light intensity.
We compare the measurement results to the kinetic model of the behaviour of metastable states under illumination by Stutzman et al..

ALMY photo detectors consist of



a thin layer of **hydrogenated amorphous silicon (a-Si:H)** between two transparent layers of indium-tin-oxide (ITO) electrodes (64x64 gitter), deposited on a 1 mm thick glas substrate.



Detectors provide a **2D measurement of the laser beam position with a 1 micron precision** in both directions, over a 20x20 mm^2 of sensitive area.

The laser beam has a gaussian beam profile of 2-3 mm width. Its position is **given by** the two centroids of the **photo current distribution** on the bottom and the top strips.

Photo current sensitivity under illumination

Staebler-Wronski effect (1977):

The photo current response of a-Si:H deteriorates under illumination due to the creation of additional metastable states in the band gap of amorphous silicon which decreases the life-time of excess cariers and thus reduces the photoconductivity.

Prediction by the kinetic model of Stutzman et al.

SHORT TIME OF ILLUMINATION

$$\frac{s(t)}{s_0} = (1 + A I^2 t)^{-1}$$

$s_{(0)}$ - (initial) photo current sensitivity
t - illumination time
I - laser beam intensity
A - material dependent constant

LONG TIME OF ILLUMINATION

$$\frac{s(t)}{s_0} = (1 + 3 A I^2 t)^{-1/3}$$

Long-term study using ALMY detectors

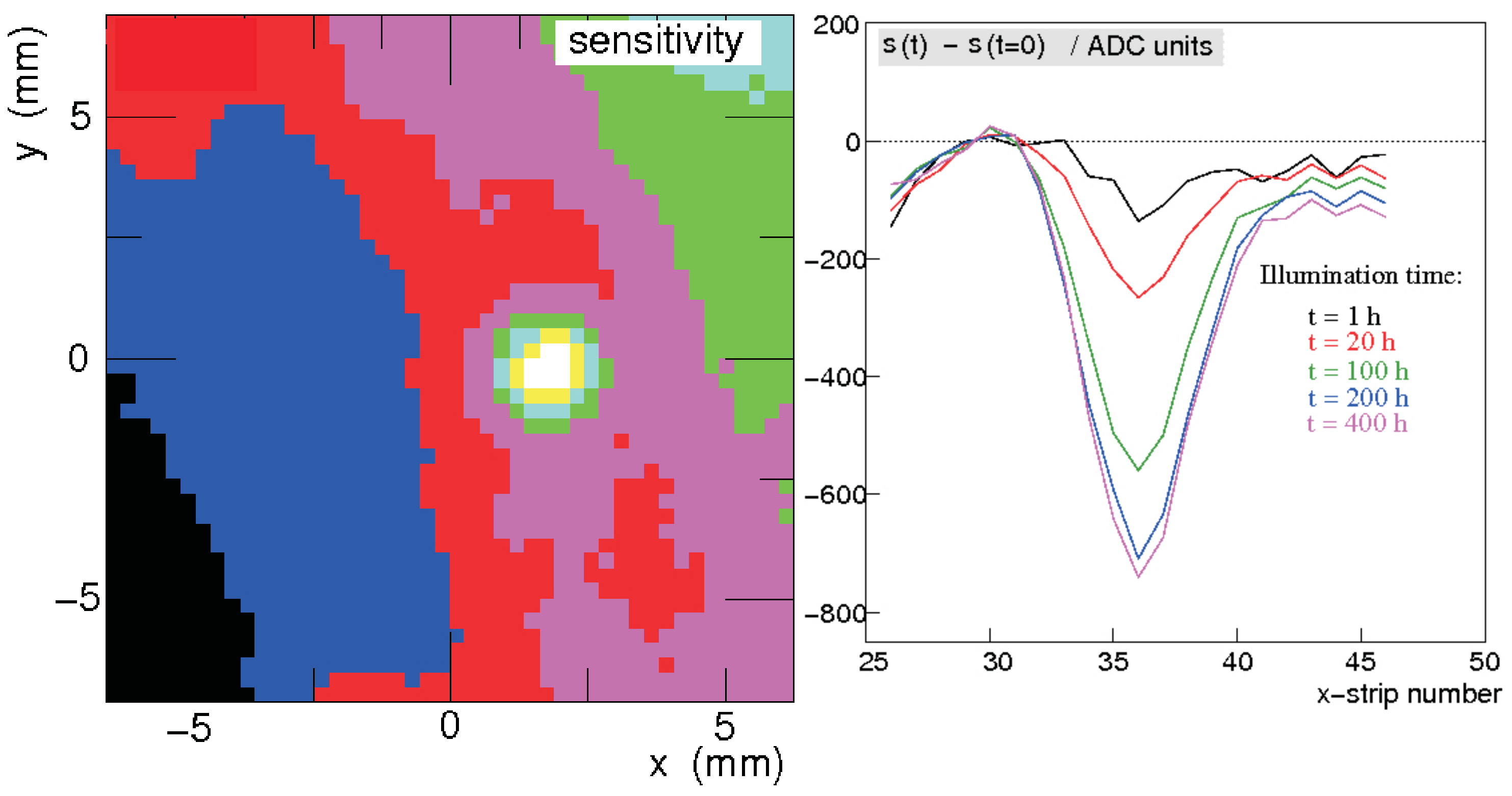
ALMY detecors are **continuously illuminated** by a laser beam **at a fixed position**. The photo current sensitivity (s_{illum}) at the illumination point is monitored in time with respect to the photo current sensitivity (s_{base}) on the rest of the sensor surface.

Monitoring is performed via the scan of the sensor surface using a test laser. Sensitivity degradation is described by the ratio

$$\frac{s(t)}{s_0} = \frac{s_{illum}(t) - s_{base}(t)}{s_{illum}(t=0) - s_{base}(t=0)},$$

such to avoid the systematic errors from the variations of the test laser intensity.

LOCAL DEGRADATION OF THE SENSITIVITY
OBTAINED FROM THE SCAN OF THE SENSOR SURFACE



Fit of the theoretical model to the measured data:

SHORT TIME OF ILLUMINATION

$$\frac{s(t)}{s_0} = (1 + a_{short} t)^{-1}$$

LONG TIME OF ILLUMINATION

$$\frac{s(t)}{s_0} = (1 + a_{long} t)^{-1/3}$$

and

$$a_{(short,long)} = A_{(short,long)} I^b$$

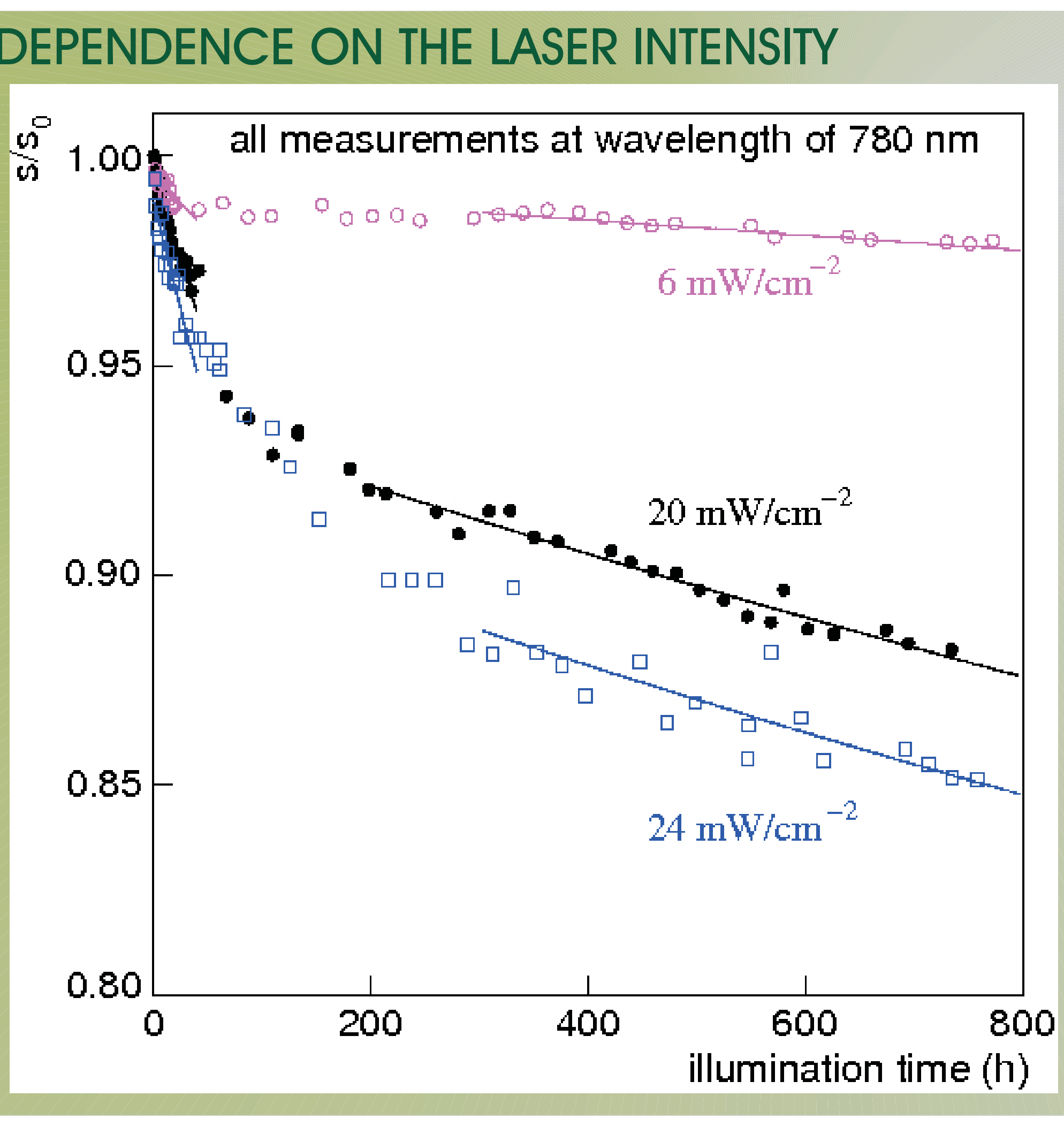
	$a_{short} / 10^3 s^{-1}$	$a_{long} / 10^3 s^{-1}$	
780 nm, $I = 7$ mW/cm^{-2}	0.41 ± 0.01	0.05 ± 0.01	$b = 1.7 \pm 0.3$
780 nm, $I = 20$ mW/cm^{-2}	1.00 ± 0.03	0.27 ± 0.01	
690 nm, $I = 0.6$ mW/cm^{-2}	0.96 ± 0.03	0.37 ± 0.01	
780 nm, $I = 24$ mW/cm^{-2}	1.19 ± 0.05	0.32 ± 0.01	

SHORTER ILLUMINATION INTERVALS:
Good agreement with the kinematic model.

LONGER ILLUMINATION INTERVALS:
Qualitative agreement with the kinematic model:
- quadratic dependence on the laser intensity
- no dependence on the laser wavelength,

but
photo current sensitivity decreases slower than what is expected from the initial degradation rate (i.e. $a_{long} = 3a_{short}$ expected; $a_{long} = 0.3a_{short}$ observed).

DEPENDENCE ON THE LASER INTENSITY



DEPENDENCE ON THE LASER WAVELENGTH