

# Imaging Without Optics: Localization of Radiation Sources Using Flat Lensless Sensors

Stanislav Umansky

Supervisor: Prof. L. Yaroslavsky

## Motivation

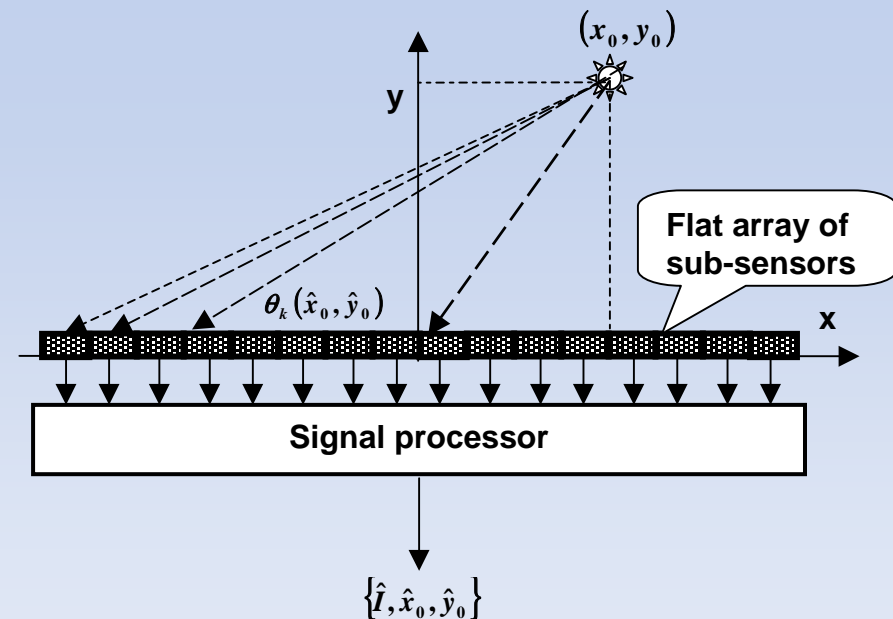
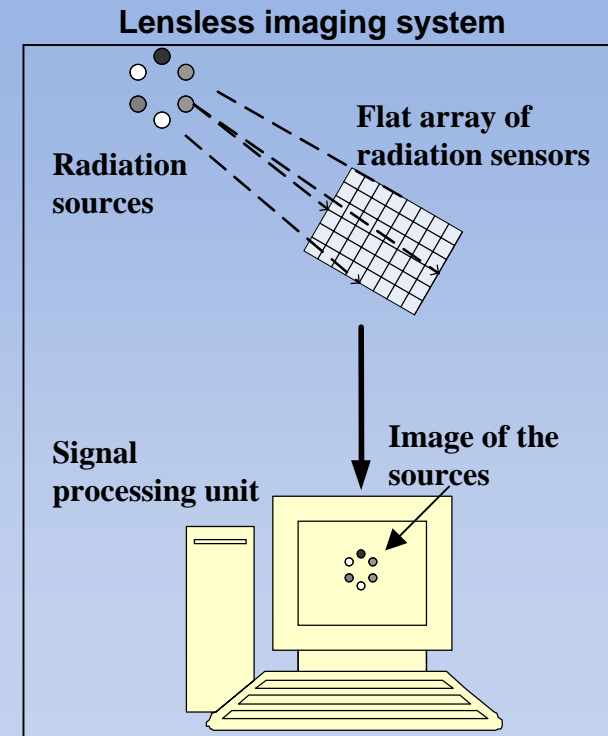
- Imaging when optics are not available or non applicable
- Miniaturization and cost reduction of existing optical systems

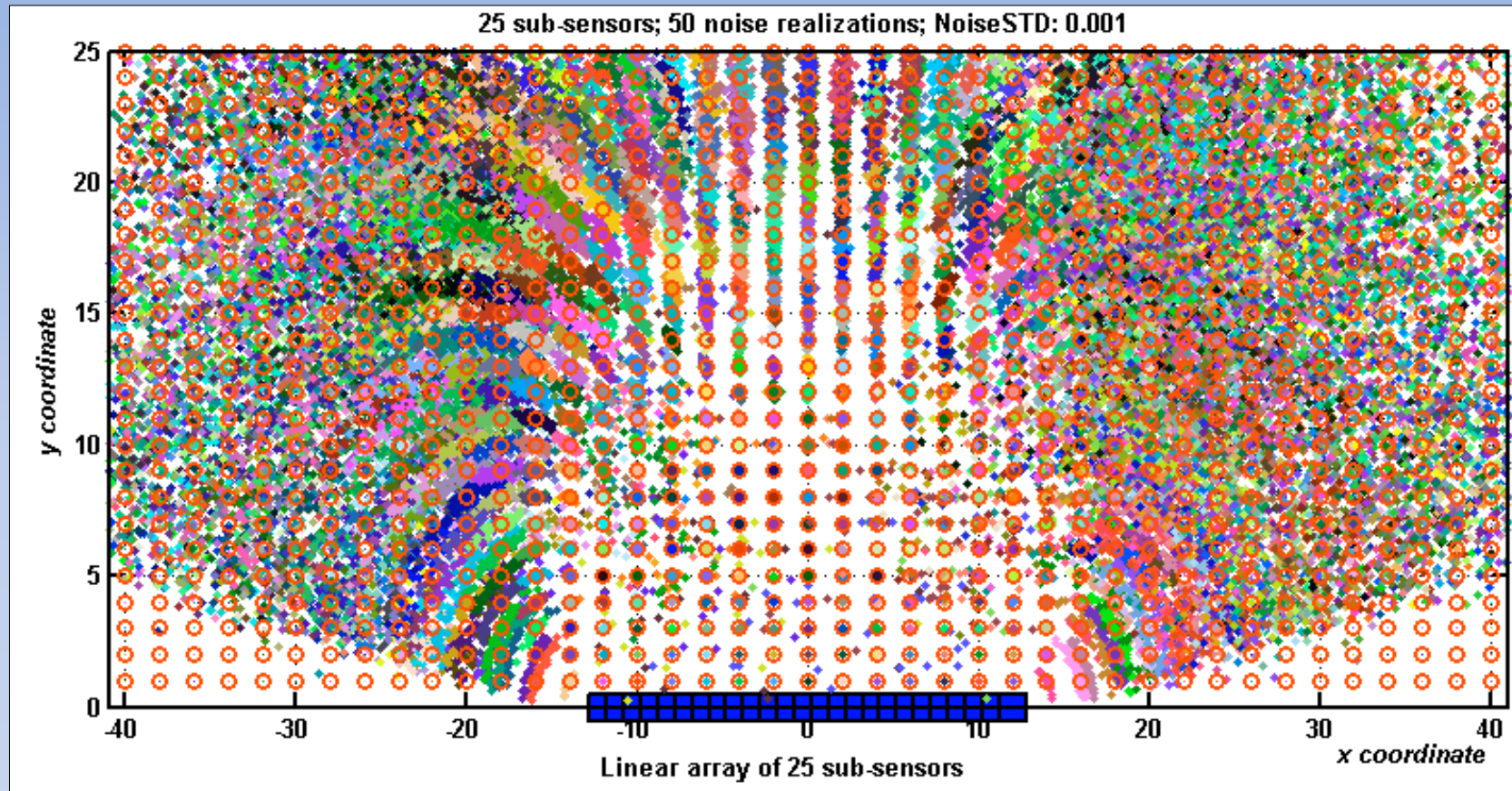
## Operational principle

- Treating the image as a finite set of a point sources
- Imaging by means of lensless sensor array consisting of a set of sub-sensors with cosine-law angular sensitivity and distributed over a flat or bent surfaces
- Computational image formation through estimating point sources' locations and radiation intensities by means of applying to data collected from the sensor array the Maximum Likelihood (ML) estimation method

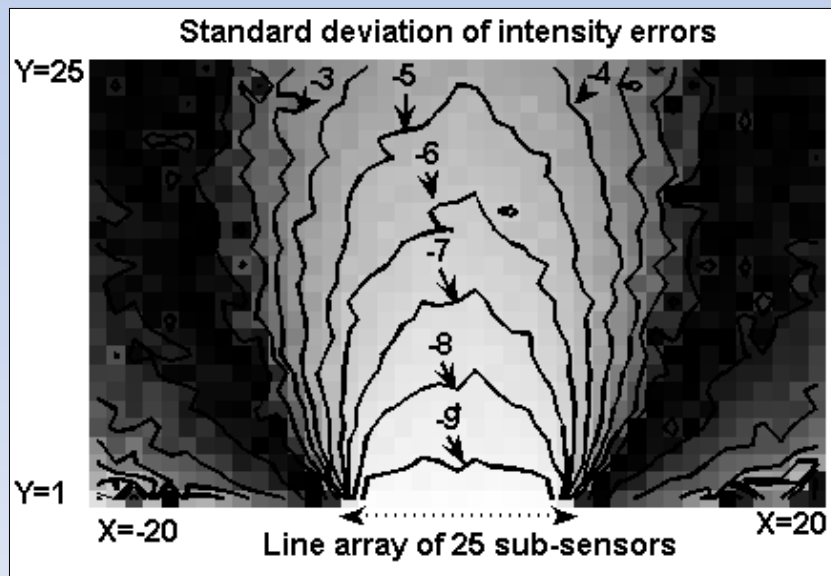
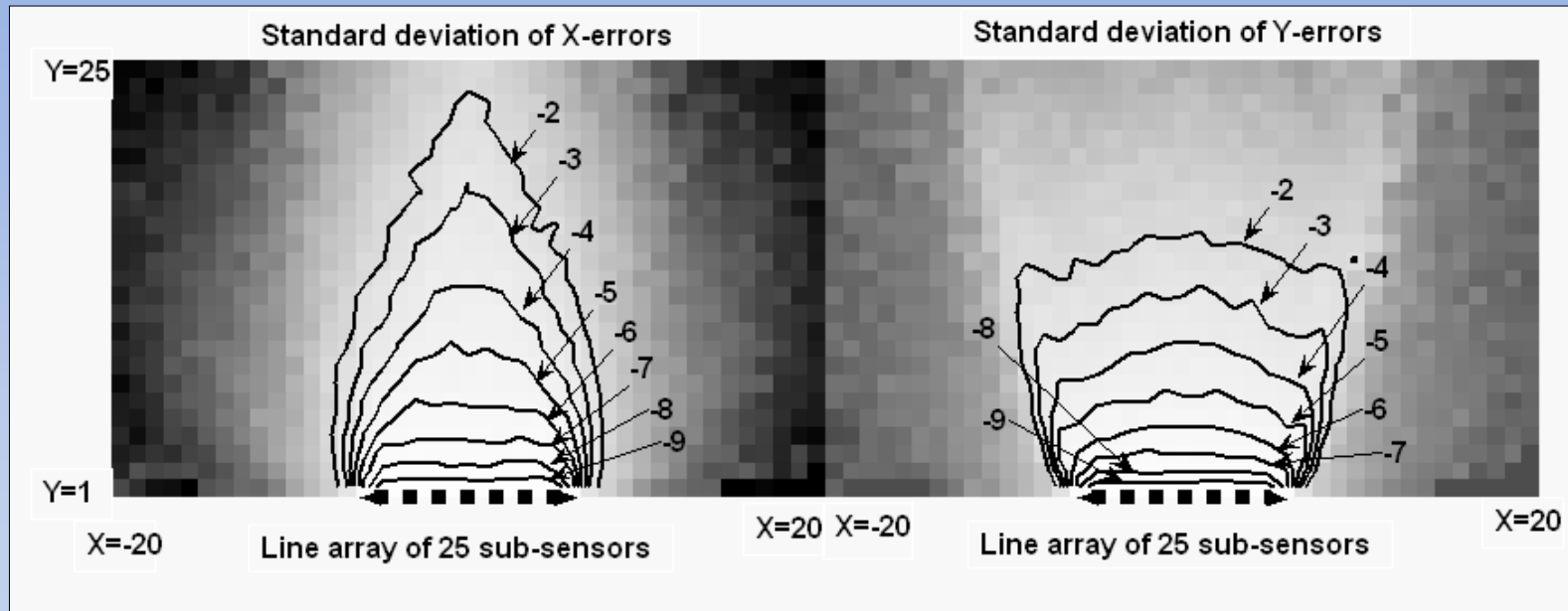
## Method

- Numerical simulation for determining imaging formation capability in terms of errors in estimates of radiation source coordinates and intensities for different number of sub-sensors and their signal-to-noise ratios and sensor surface geometry (flat vs. bent)





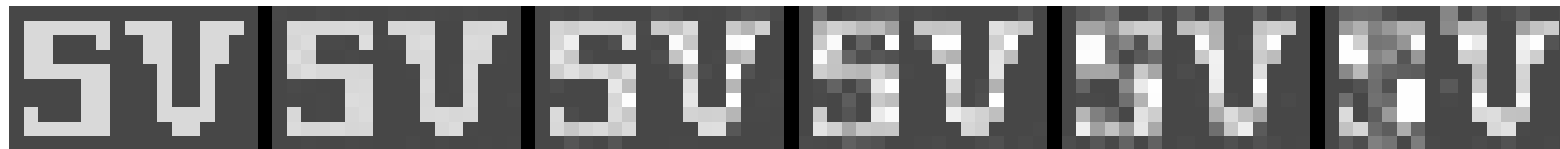
Spread of “hits” in estimating X-Y coordinates of a single source by a flat sensor array consisting of 25 sub-sensors



- Standard deviation of estimation errors of X-Y coordinates and of intensity of a radiation source as a function of the source position with respect to the sensor. (Darker areas correspond to larger errors. Numerical values of coordinates are shown in the units of the inter-sub-sensor distance. Numerals at lines of the contour maps indicate exponent of 2 of numerical values of the error standard deviation in same units)

# Flat lens-less sensor in the imaging mode

Flat sensor; 30 sub-sensors; NoiseStd=0.01



Source  
matrix

Y=1

Y=2

Y=3

Y=4

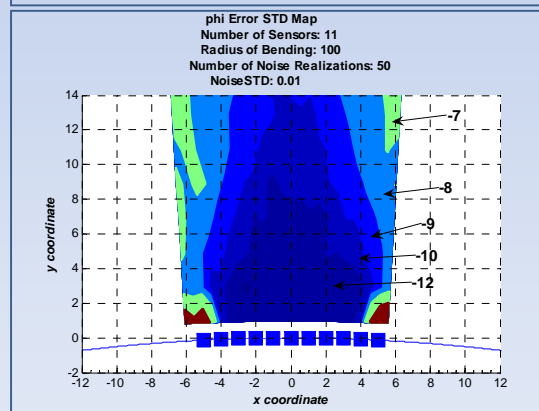
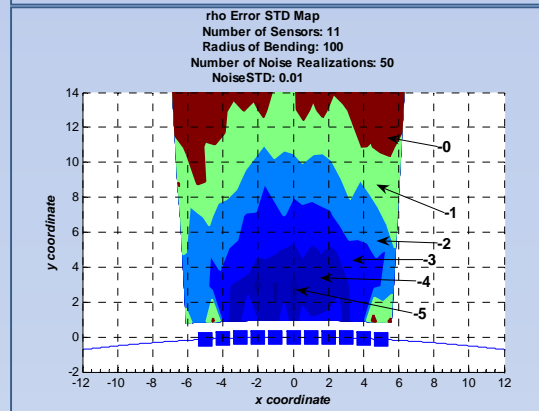
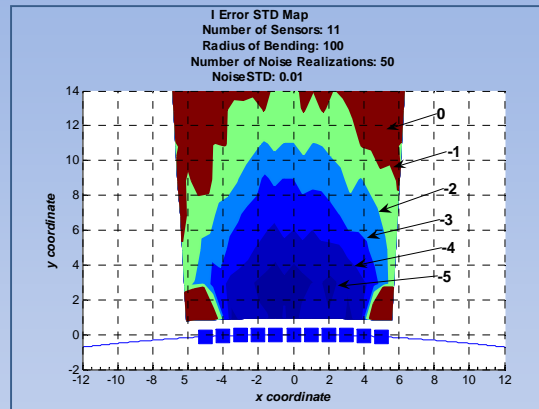
Y=5

Sensing of 10x16 radiation sources arranged on a plane in form of characters “SV” by a 1-D model of a flat OLS sensor of 30 elementary sub-sensors in the “imaging” mode for distances of sources from the sensor  $Y=1$  to 5 (in units of inter-subsensor distance). The source matrix was scanned column-wise. Standard deviation of subsensors’ noise was 0.01 (in units of the source intensity dynamic range [0 1])

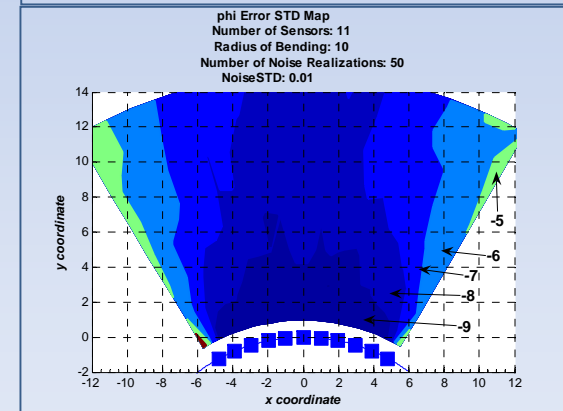
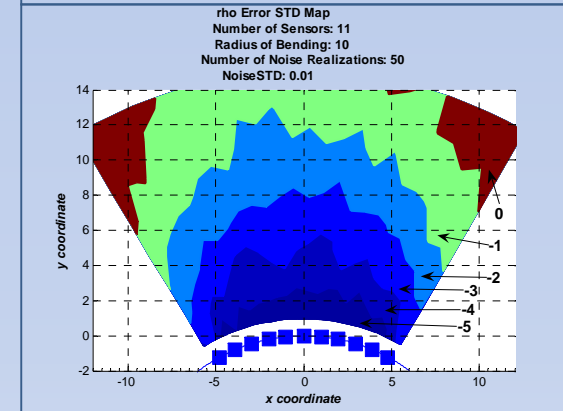
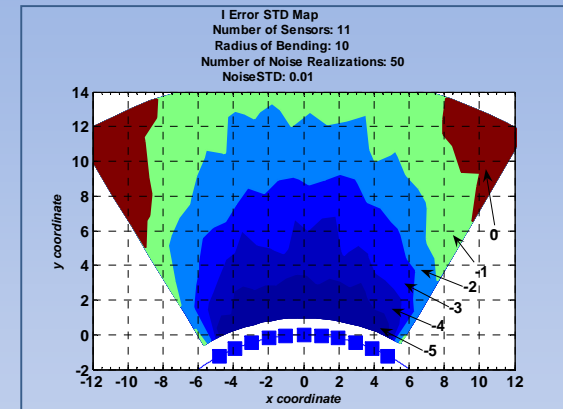
# Bent sensor on a convex surface

*Standard deviations of estimation errors of X-Y coordinates and of intensity of a radiation source. Contour labels stand for the power of 2 order of estimation error standard deviation.*

### Sensor on a sphere of radius 100



### Sensor on a sphere of radius 10



## **Results**

- **Flat lens-less sensors are capable of imaging with fair quality within the field of view of about a sensor size in the direction parallel to the sensor surface and half its size in the perpendicular direction**
- **Variances of source coordinates and intensities estimation errors are inversely proportional to the number of sub-sensors and their signal-to-noise ratio**
- **Sensor can resolve two point sources if the distance between them exceeds inter sub-sensor distance**
- **Bending the sensor's surface to a convex spherical form widens the sensor's field of view and improves its ability to resolve more distant points**