Institute of Applied Physics
Friedrich-Schiller-Universität Jena

Metrology and Sensing

Lecture 3-3: Sensors

2020-11-17

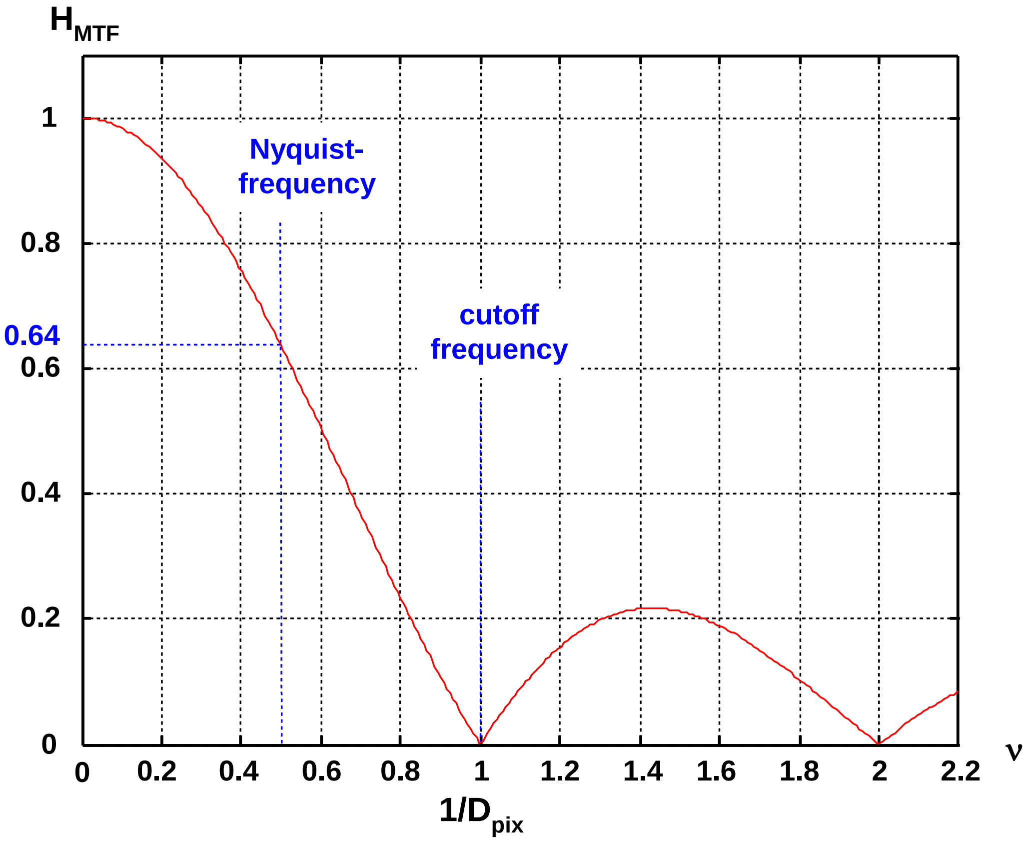
Herbert Gross

Content

- Filtering
- Noise

Detector Sampling

- Discrete pixelized detector: sinc-transfer function



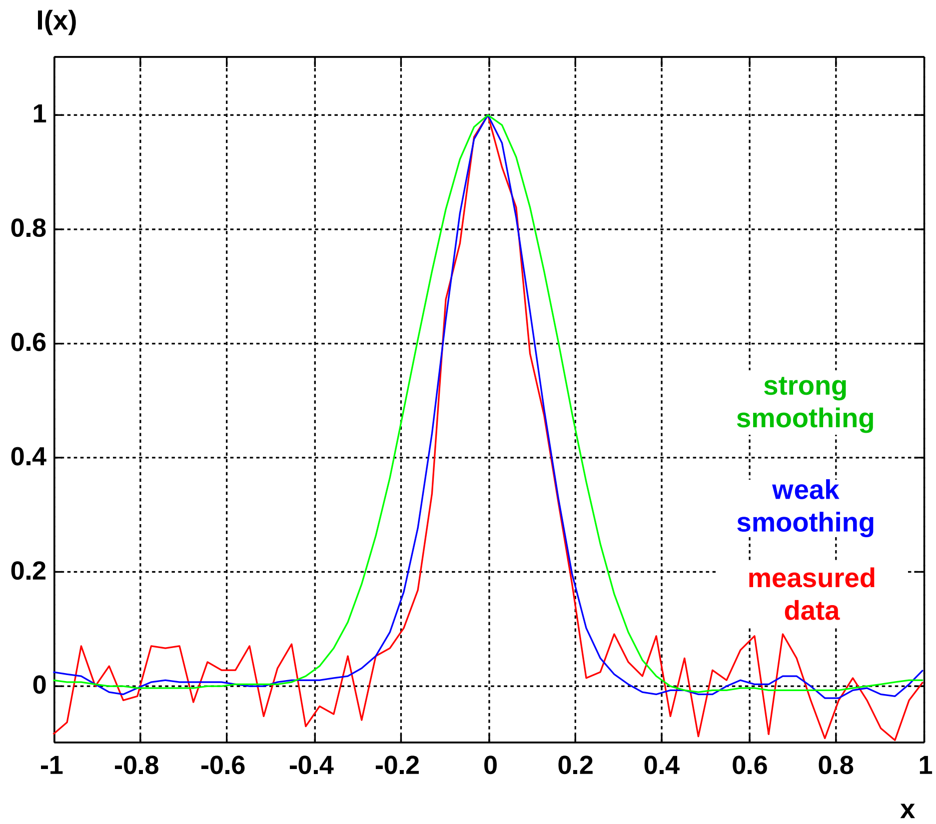
Signal Filtering

- Low-pass filtering:
  suppression of high-frequency signals

- Numerical realization:
  - Fourier spectrum limited
  - smooth truncations filters to avoid
    oszillations

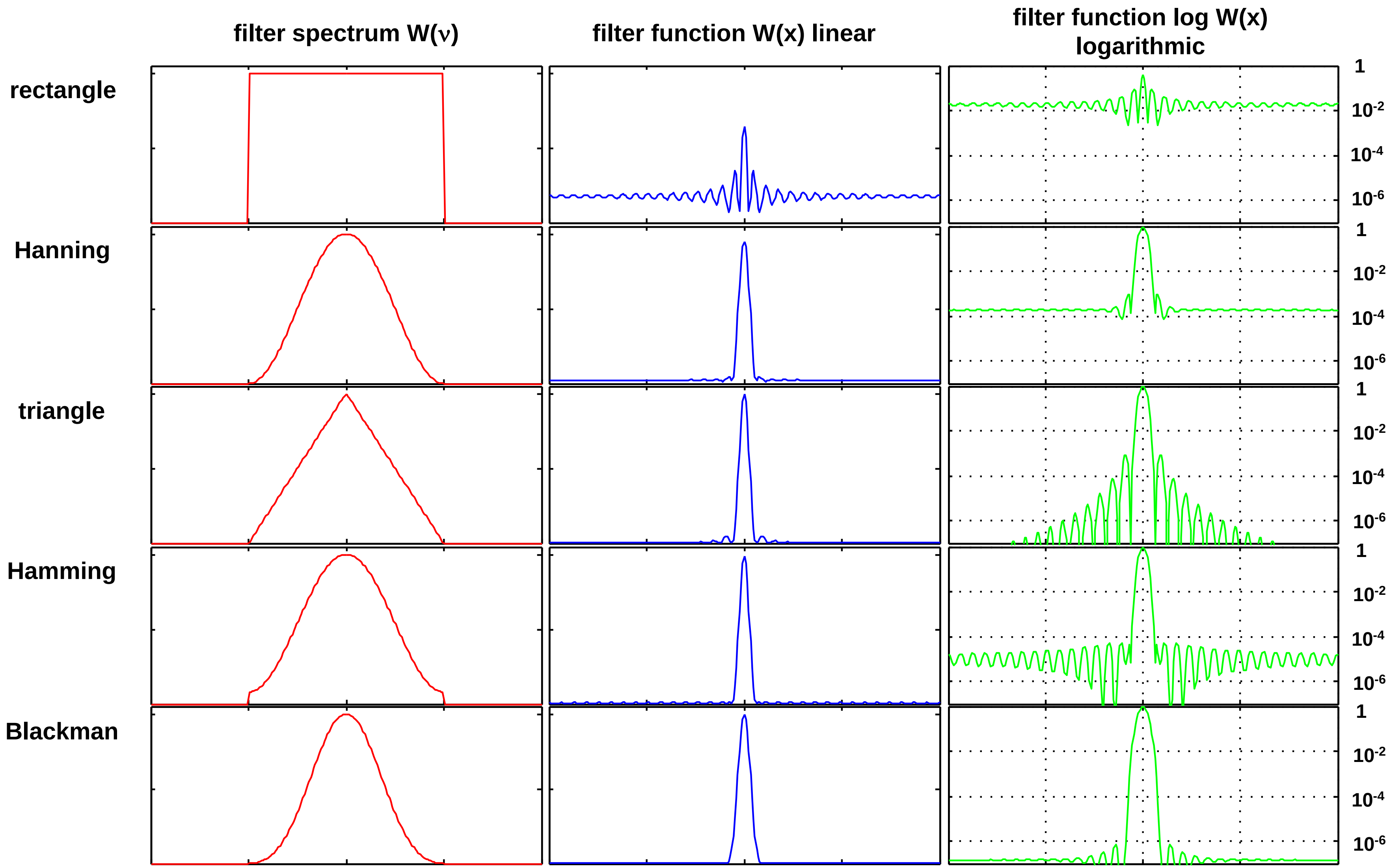
- Typical effects:
  - side lobes
  - reduced gradients
  - higher frequencies damped

- Well known filter solutions:
  - rectangle
  - Hanning
  - Hamming
  - Blackman
  - Bartlett, Dreieck



Signal Filtering

Institute of Applied Physics
Friedrich-Schiller-Universität Jena

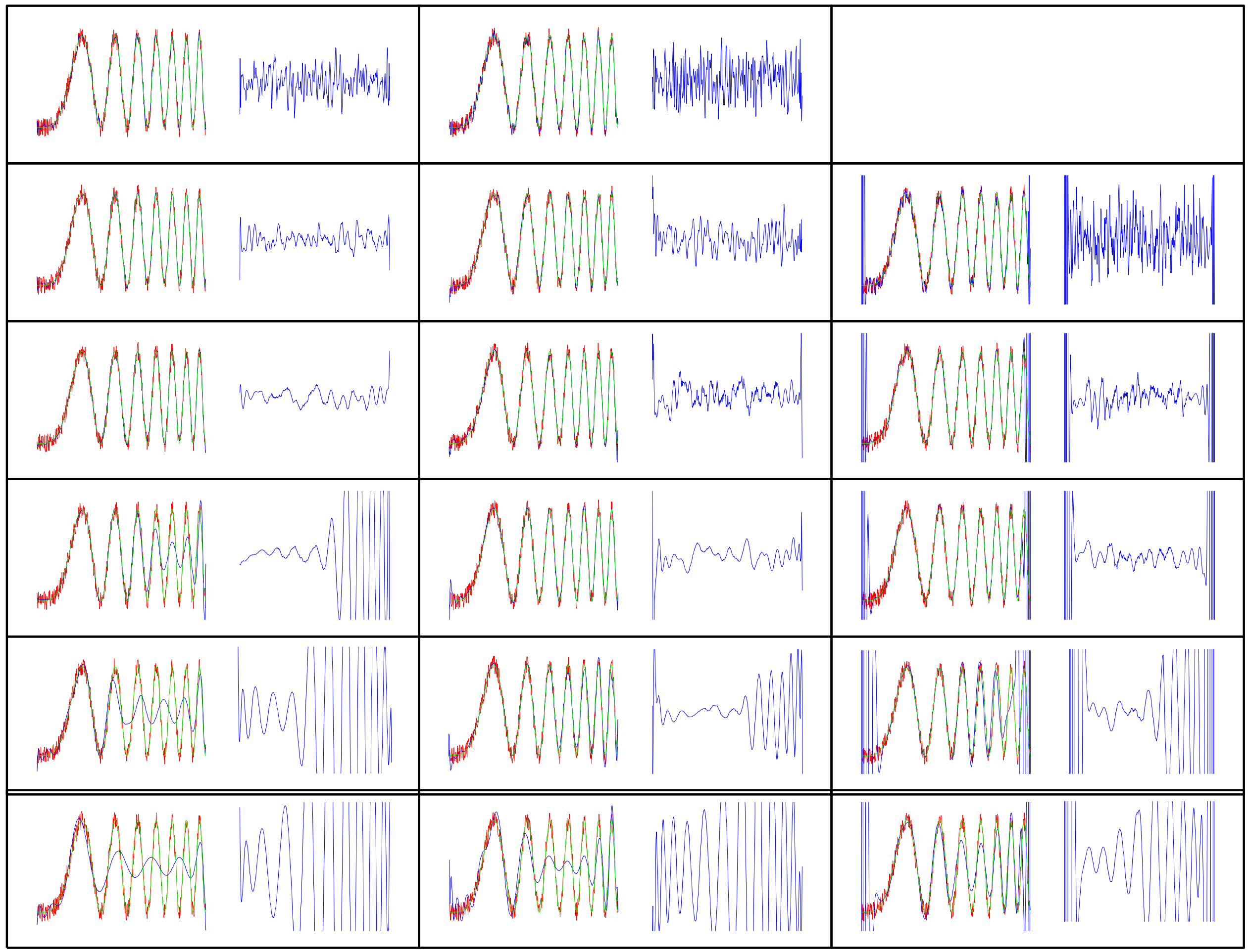


Savitzky-Golay Filter

- Fit of polynomial with order k and N points

- Good conservation of gradients

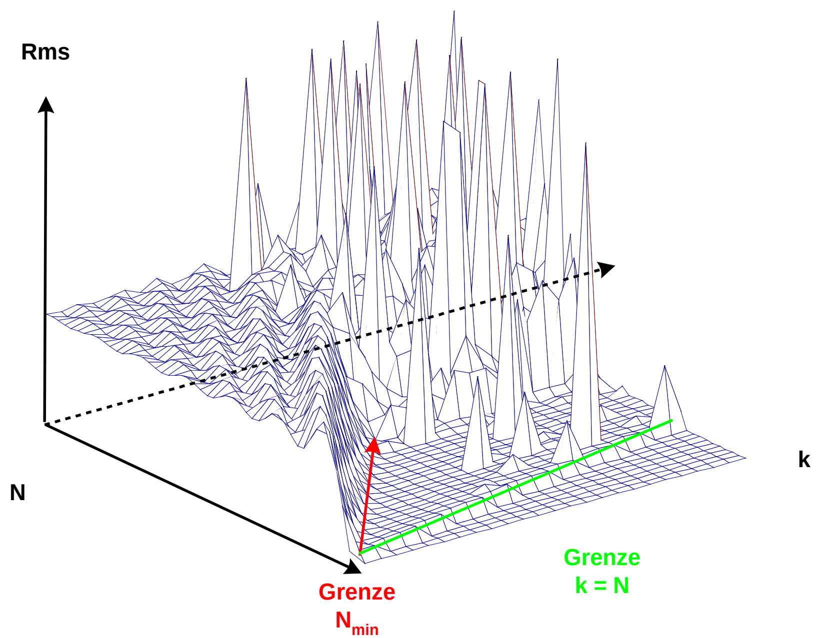
- Features with higher frequency content preserved

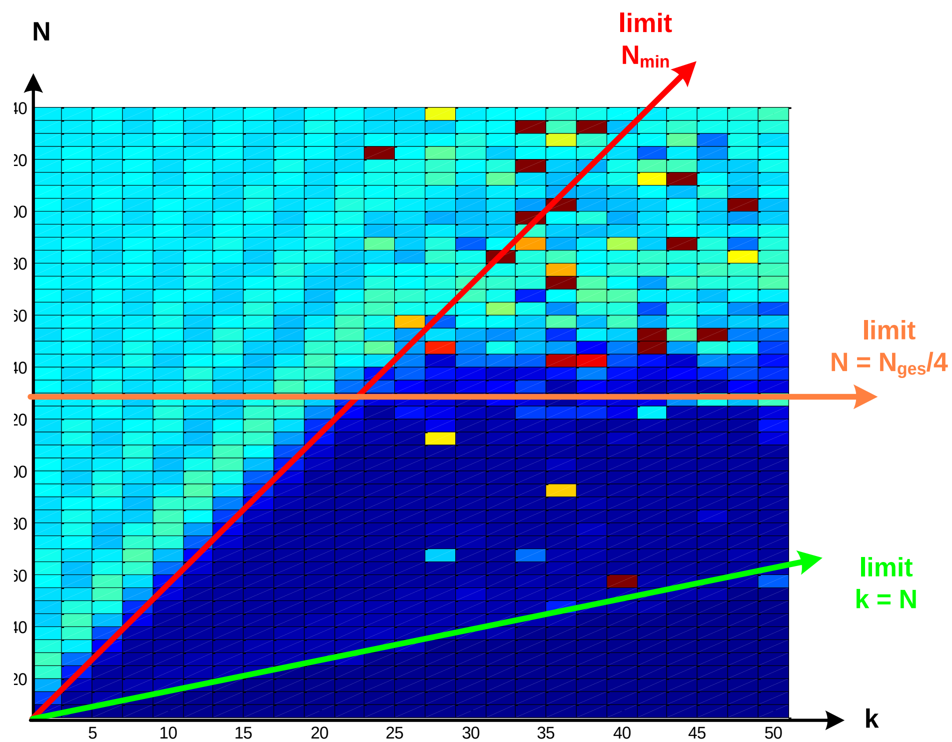


Savitzky-Golay Filtering

Institute of Applied Physics
Friedrich-Schiller-Universität Jena

Optimization of
1. polynomial order k
2. number of points N





Noise

Types of noise in photo-electric sensors:

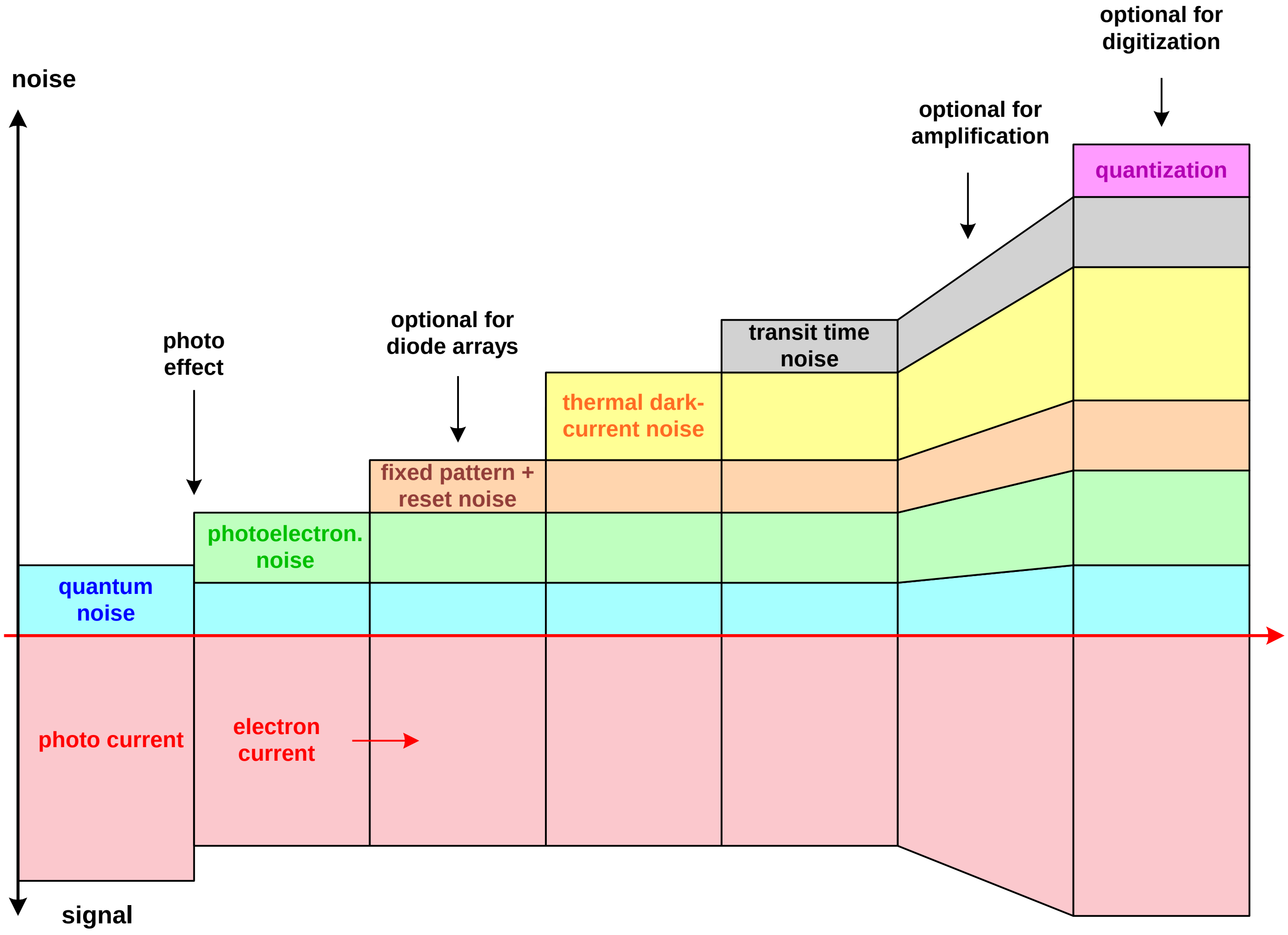
- photons noise
- Flicker noise due to elektrons
- fix-pattern noise
- Reset noise
- Dark current, Schrot, thermal noise
- Excess noise of gain
- Quantization noise

Superposition of noise reasons:

$$\left(\frac{S}{N}\right)_{many} = \sqrt{n} \cdot \left(\frac{S}{N}\right)_{\sin gle}$$

Noise

Generation of noise in photo-electric sensors



Noise

- Thermal white noise

$$P_R = 4k_B T$$

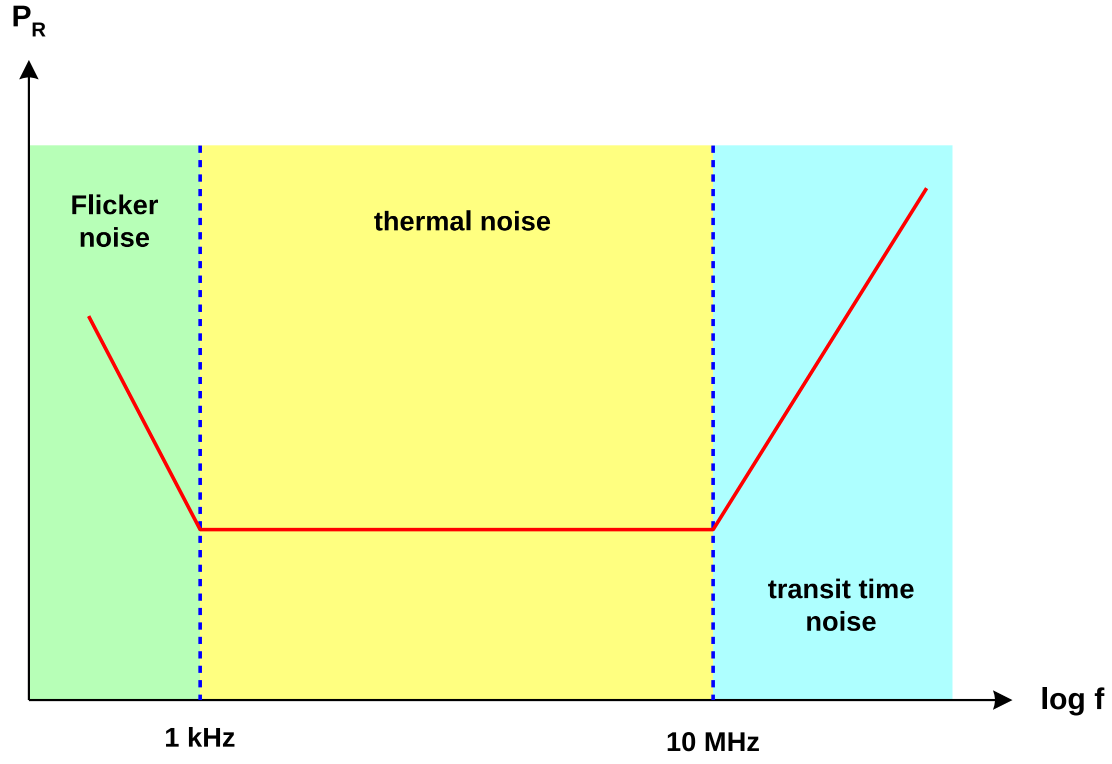
- Flicker noise

$$P \propto \frac{1}{f}$$

- Schottky noise of runtime

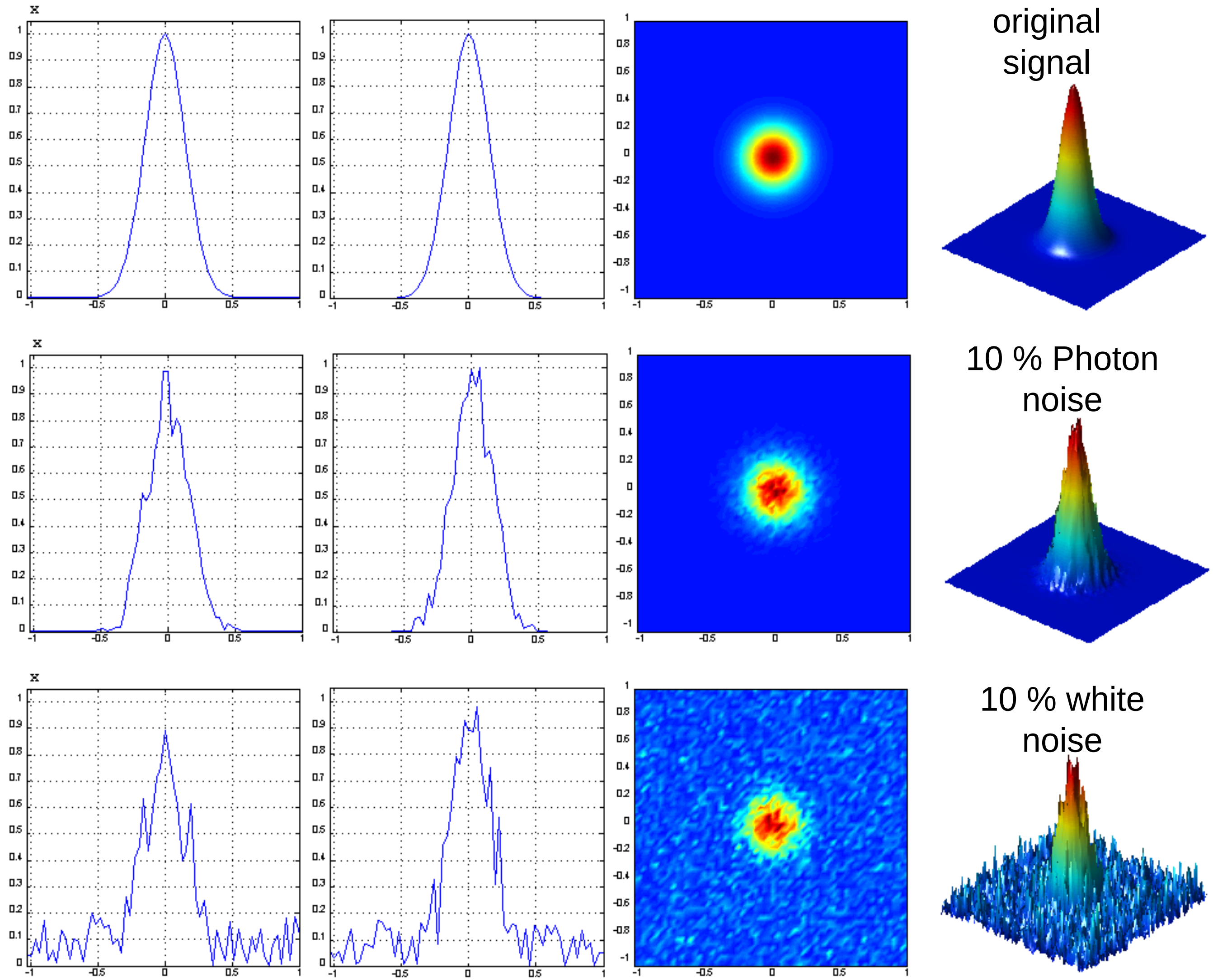
$$P = 2e \cdot \Delta f \cdot I_0 \cdot R$$

- Dominating noise depends on frequency



Quantum Noise

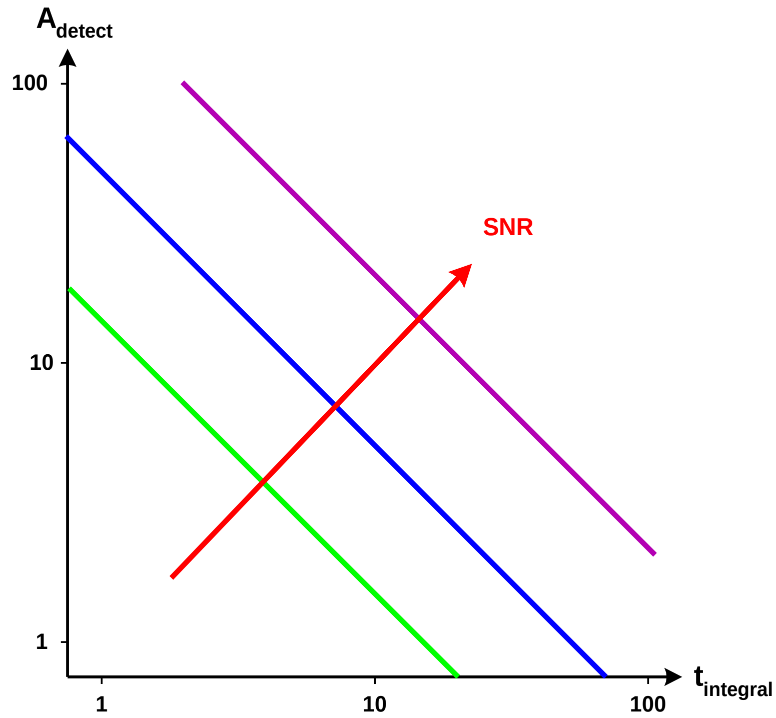
Poisson noise
and white noise



Characteristic:

Noise grows with
1. time of integration

2. size of detector area



Background Noise

Institute of Applied Physics
Friedrich-Schiller-Universität Jena

Noise reduction and subtraction of background