# Acoustic Field Characterization with Schlieren System


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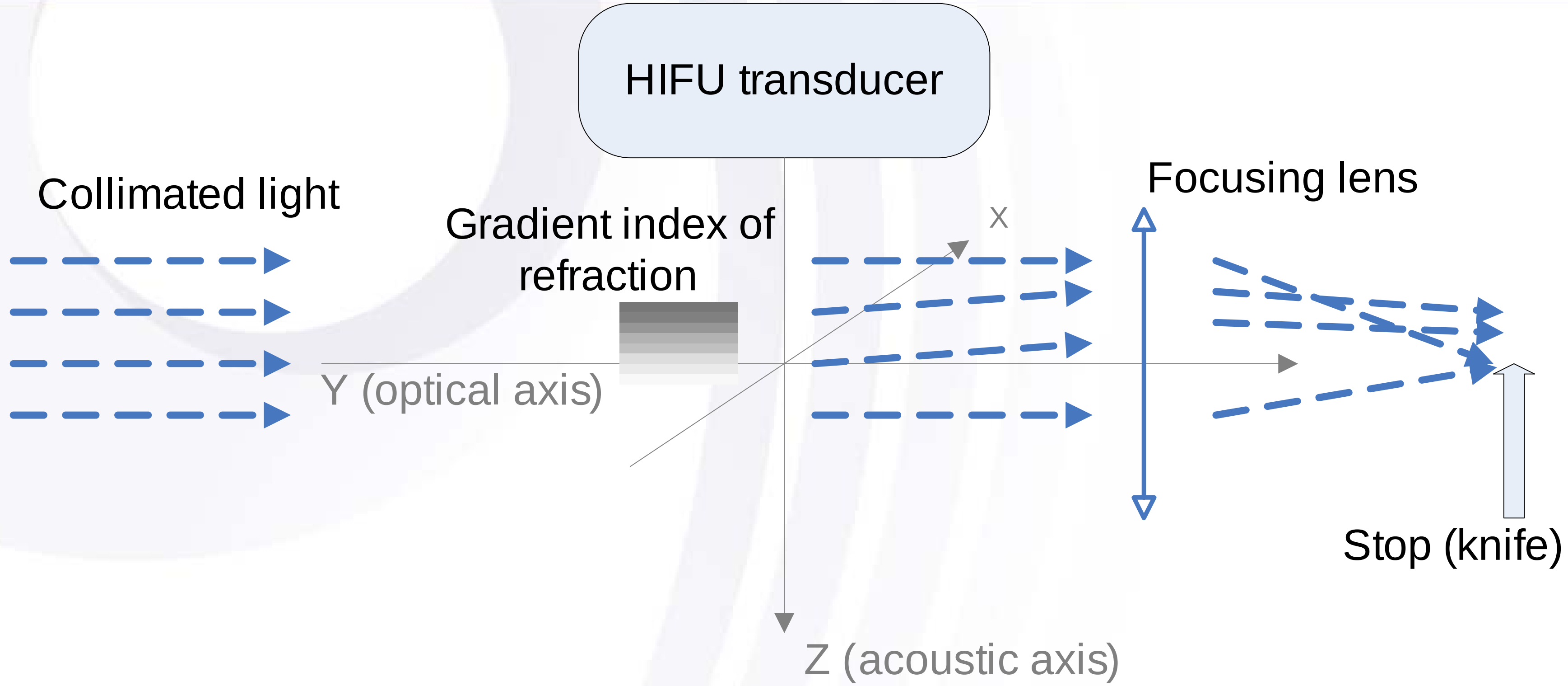
# The acousto-optic effect




Spatial pressure gradients
induce gradients in index of refraction
All the parallel light impinges on the stop
Only the deflected light passes the stop

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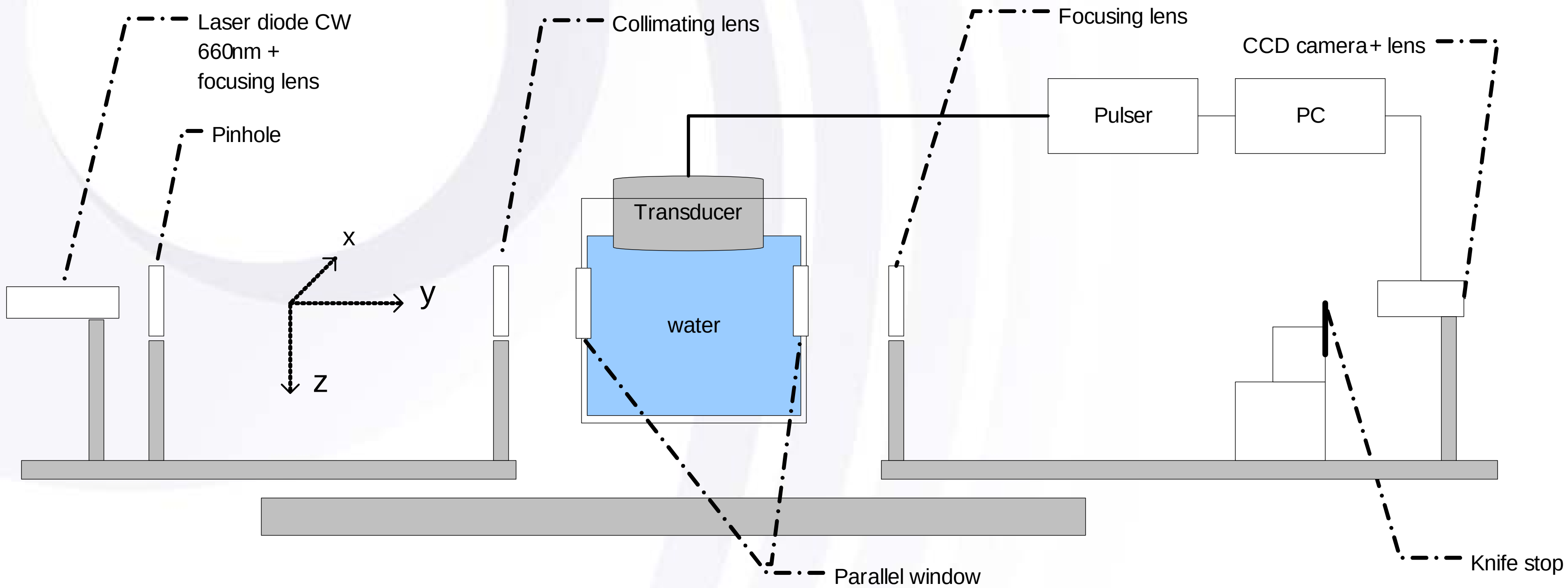
# Setup of linear Schlieren apparatus

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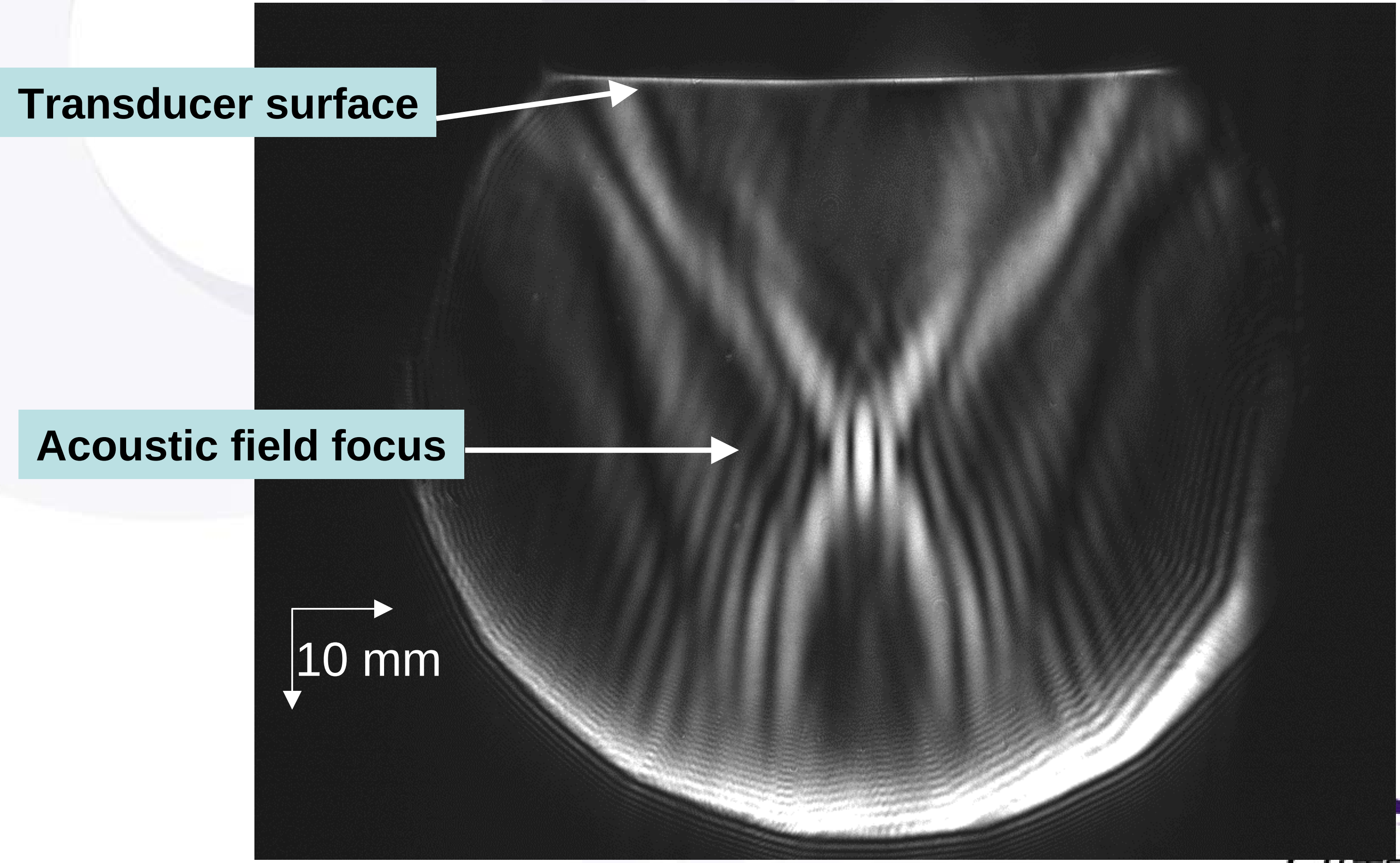
# Schlieren image of HIFU (High frequency)

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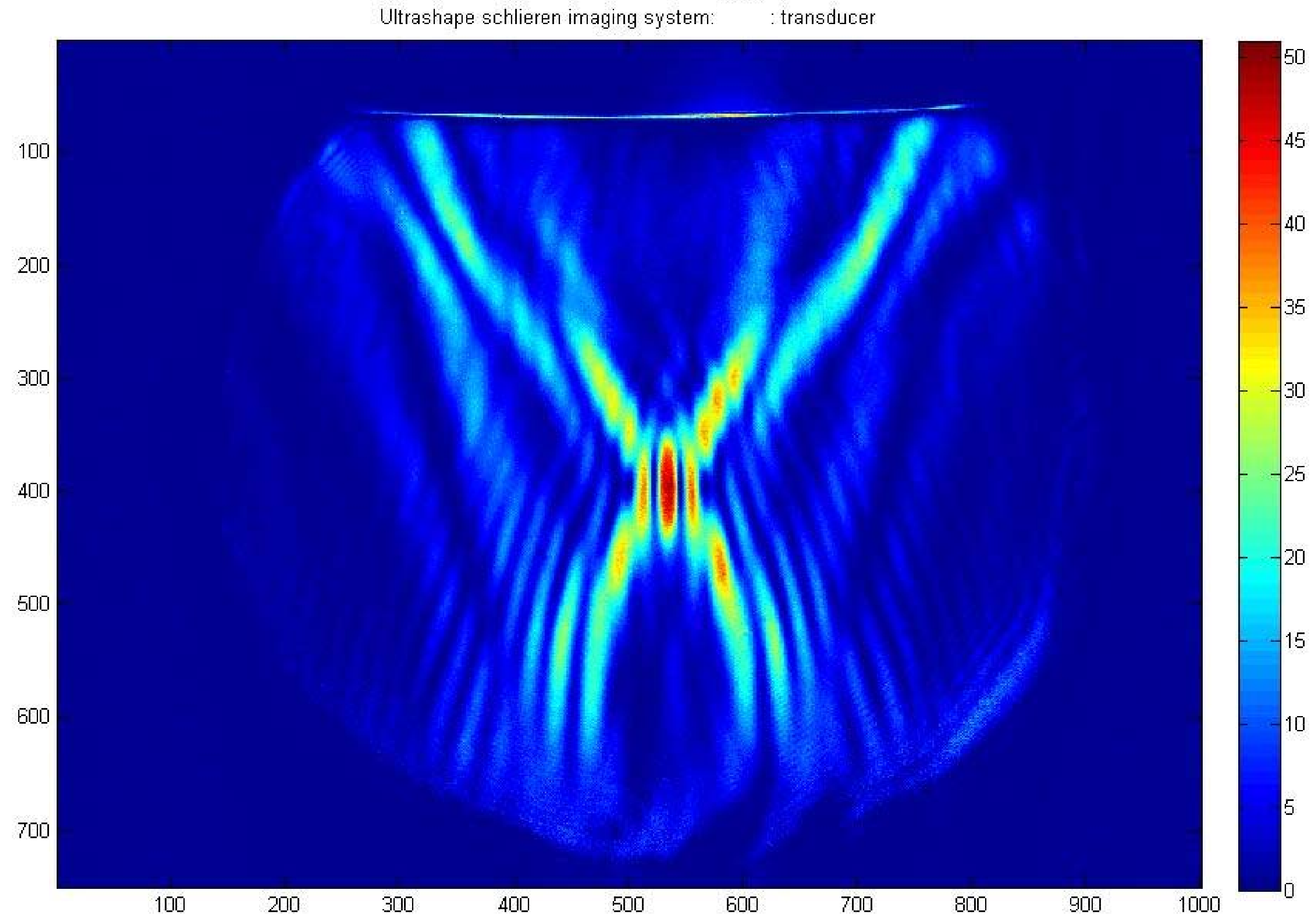
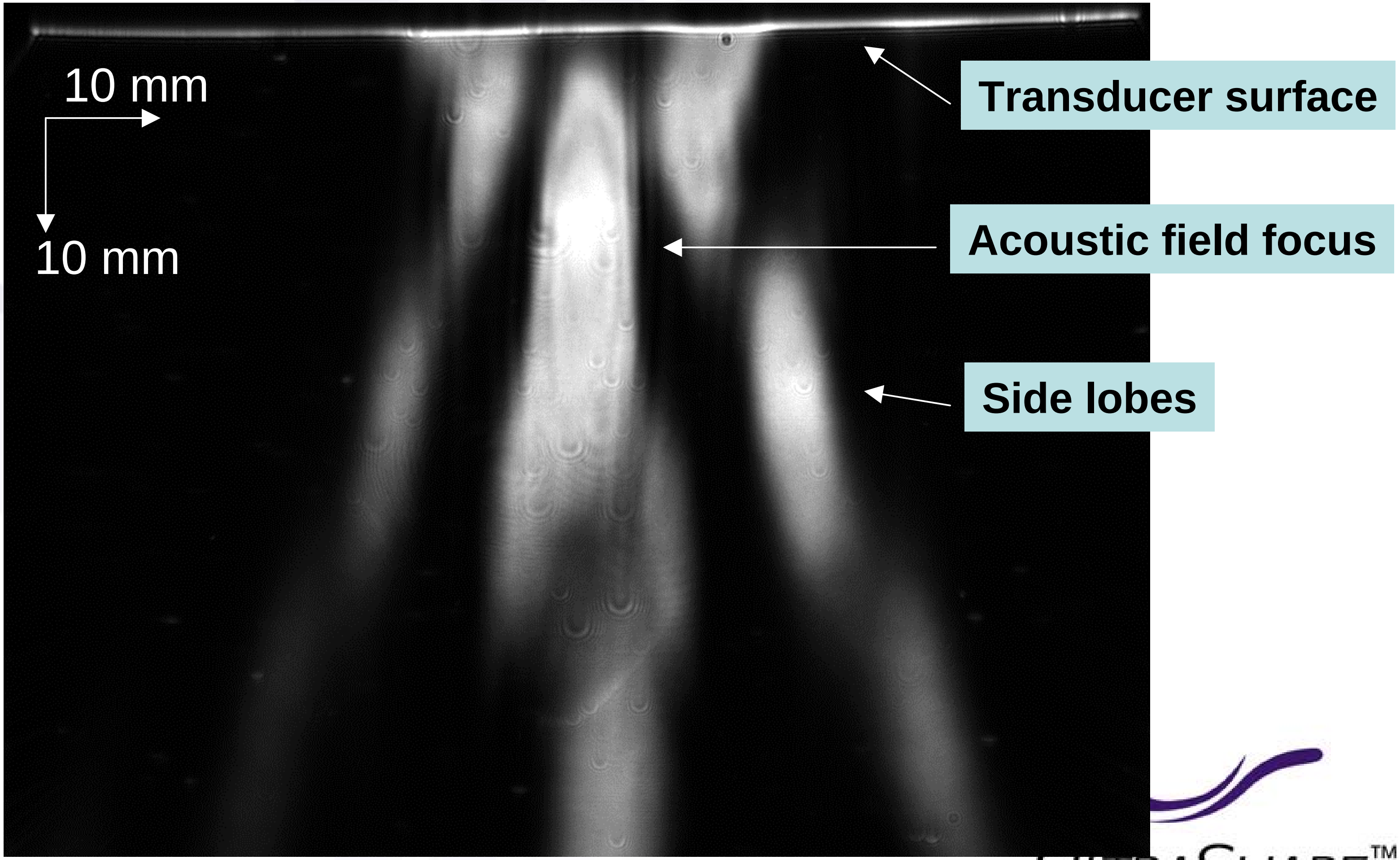
# High frequency HIFU – image processed



# Schlieren image of HIFU – Low frequency

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# Schlieren Visualization Modeling

Given data of the complex amplitude of pressure field over the plane perpendicular to the transducer axis, $P(x,y,z_0)$,

1. The angle spectrum $\hat{P}\left(k_x, k_y, z_0\right)$ is calculated with 2D FFT
2. The distribution of phase deviation of electromagnetic wave due to piezo-optic effect is obtained on the base of formula:

$$\Phi(x,z) = \int_{y_0}^{y_0+L} P(x,\eta,z)\, d\eta \approx 1/2\pi \int \hat{P}(k_x, 0, z_0)\, e^{i\left(k_x x + (z - z_0)\sqrt{k_{acoust}^2 - k_x^2}\right)} dk_x$$

3. The light intensity distribution over the observation screen is

$$I(x,z) = \frac{1}{4}\left[1 + \frac{k_{opt}^2 \mu_p^2}{\pi^2}\left| Pv \int_{-\infty}^{\infty} \frac{\Phi(-x, -z')dz'}{z - z'} \right|^2\right]$$

Here $\mu_p = \partial\mu / \partial p$ is piezo-optic constant, $\mu$ is refractive index

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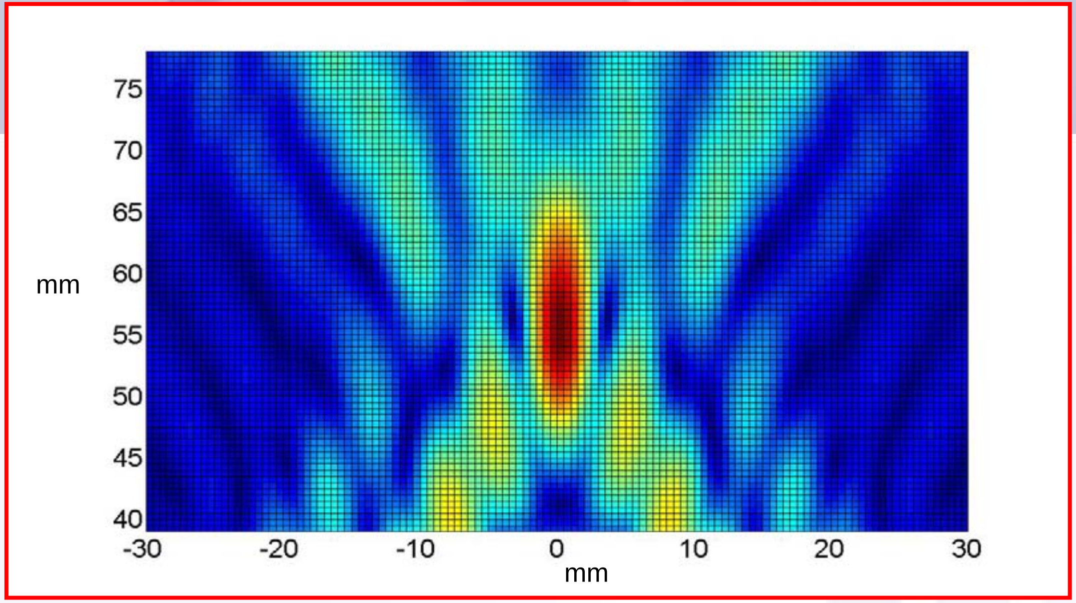
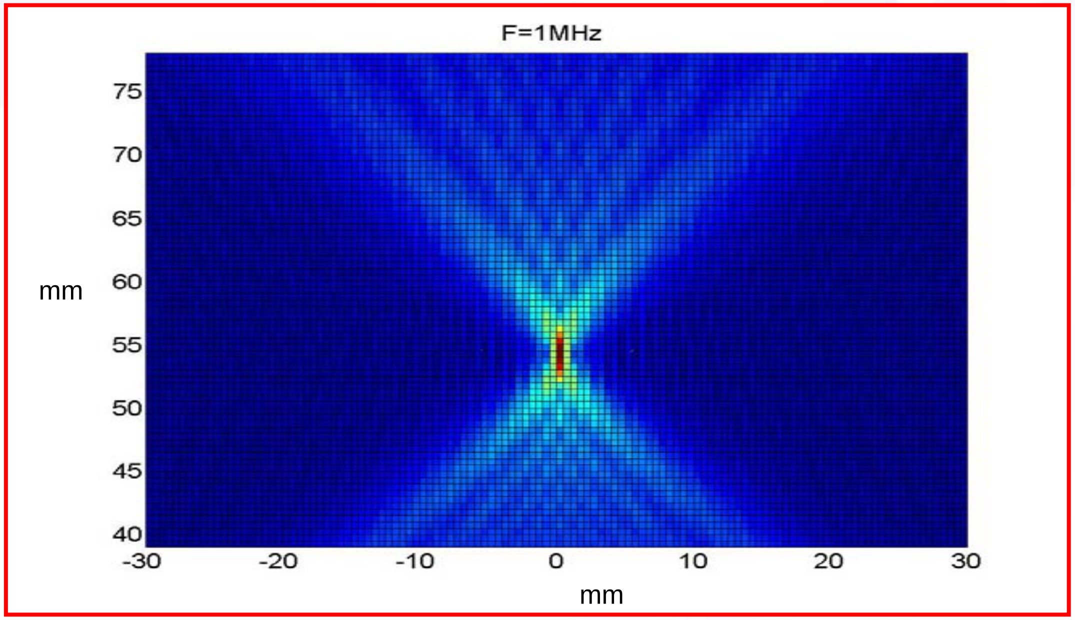
# Numeric Modeling Patterns




## Low frequency

The pressure distribution over the focal plane was measured

## High frequency

The pressure distribution over the focal plane was calculated on the basis of the uniformly vibrating transducer model

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# Conclusions…

- **Advantages**
  - Fast mapping of the acoustic field
  - No distortion of the acoustic field
  - High intensity measurements
- **Disadvantages**
  - Projections of the acoustic field
  - Qualitative tool
- **What next…**
  - Implement tomography to construct the 3D pressure field from a set of projections
- **References**

  - Settles, G. S., *“Schlieren and Shadowgraph Techniques”*, Springer (2001)
  - Raman, C. V. and Nath, N. S., Proc. Indian Acad. Sci. II, 406 (1935)
  - Hanafy, A. and Zanelli, C. I., IEEE Ultrasonics Symp. Proc., 1223 (1991)


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