TEMPERATURE DISTRIBUTION AND IT’S INFLUENCE ON PIEZO-PAS CHARACTERISTICS
THEORETICAL APPROACH

M. Maliniski
Faculty of Electronics, Technical University of Koszalin
17 Partyzantów St Koszalin, Poland.

The General Temperature Distribution Equation  \( T(x, \beta, l, \alpha, f, R) \) describes the spatial distribution of the periodical contribution of the temperature alongside the thickness of one layer sample placed on a thermally thick backing material thermally conducting or insulating.

**Definitions:**
- **x** - coordinate, \( \beta \) - optical absorption coefficient, \( l \) - thickness of the sample, \( \alpha \) - thermal diffusivity, \( f \) - frequency of modulation, \( R \) - thermal reflection coefficient sample-backing.

**Practical temp. distributions (Case of GaAs)**

- **Fig. 1.** The schematic diagram of the theoretical situation considered.

- **Fig. 2.** Schematic presentation of the four thermal wave contributions to the temperature \( T(x') \) at the point \( x' \). \( X \)-notes the place of the original generation of the temperature. An assumption \( x > x' \).

\[ T(x', t) = T(x') \cdot \exp(i \cdot \omega \cdot t) \]

**Insulating Backing Material.**

\[
\begin{align*}
T(x') &= \frac{\beta \cdot I_0}{2 \cdot \lambda \cdot \sigma \cdot (1 - \exp(-2 \cdot \sigma \cdot l))} \cdot [M(x') + N(x')] \\
M(x') &= \frac{\exp(-2 \cdot \sigma \cdot l) [\exp(\sigma \cdot x') + \exp(-\sigma \cdot x')] [\exp(\sigma - \beta \cdot x') - \exp(-\sigma - \beta \cdot l)]}{\beta + \sigma} \\
N(x') &= \frac{\exp(-2 \cdot \sigma \cdot l) [\exp(\sigma \cdot x') + \exp(-\sigma \cdot x')] [\exp(\sigma - \beta \cdot x') - \exp(-\sigma - \beta \cdot l)]}{\beta - \sigma}
\end{align*}
\]

**All Backing Materials.**

\[
T(x') = \frac{\beta \cdot I_0}{2 \cdot \lambda \cdot \sigma \cdot (1 - \exp(-2 \cdot \sigma \cdot l))} \cdot [M(x') + N(x')] \\
M(x') &= \frac{\exp(-2 \cdot \sigma \cdot l) [\exp(\sigma \cdot x') + \exp(-\sigma \cdot x')] [\exp(\sigma - \beta \cdot x') - \exp(-\sigma - \beta \cdot l)]}{\beta + \sigma} \\
N(x') &= \frac{\exp(-2 \cdot \sigma \cdot l) [\exp(\sigma \cdot x') + \exp(-\sigma \cdot x')] [\exp(\sigma - \beta \cdot x') - \exp(-\sigma - \beta \cdot l)]}{\beta - \sigma}
\]

**Specific temperature distributions.**

- **Temp. distribution in an opaque half infinite sample \( T(x, \beta = \infty, l = \infty) \).**

\[
T'(X') = \frac{I_0}{\lambda \cdot \sigma} \cdot \exp(-\sigma \cdot X')
\]

- **Temp. distribution in an opaque sample \( T(x, l = \infty) \).**

\[
T'(X') = \frac{\beta \cdot I_0}{\lambda \cdot \sigma} \cdot \exp(-\sigma \cdot X')
\]

- **Temp. distribution in an finite transparent sample \( T(x, I, \beta = 0) \).**

\[
T'(X) = \frac{I_0}{\lambda \cdot \sigma} \cdot \exp(-\sigma \cdot X)
\]

**Practical temp. distributions (Case of GaAs)**

Parameters: \( \alpha = 0.1 \text{cm}^2/\text{sec}, f = 400 \text{ Hz}, l = 0.053 \text{ cm}, \beta = 1000 \text{ cm}^{-1} \)
The origin of the piezo detected spectra.

Modified Jackson & Amer Equation.

\[
S = \left( \frac{1}{2} \int T(x) \cdot dx - \frac{1}{2} \cdot \int T(x) \cdot T(x) \cdot dx \right) \cdot (-1)
\]

\[S = \text{PISTON (solid line)} - \text{DRUM (dash line)}\]

R=1

Amplitudes of piston and drum vs optical absorption coefficient for different backing materials.

Phase spectra of piston and drum vs optical absorption coeff.

FULL DRUM EFFECT (amplitude & phase)
The piezo-detected PA spectra both amplitude and phase can be computed in the domain of the optical absorption coefficient as shown below.

ENERGETIC AMP. & PHASE SPECTRA OF GaAs
The piezo detected PA amplitude and phase spectra can be also computed in the domain of the energy of the absorbed photons.

It can be performed only when the dependance of the optical absorption coefficient versus the photon energy is assumed. (see the figure below)