Quartz resonator based low-energy ionizing radiation detection

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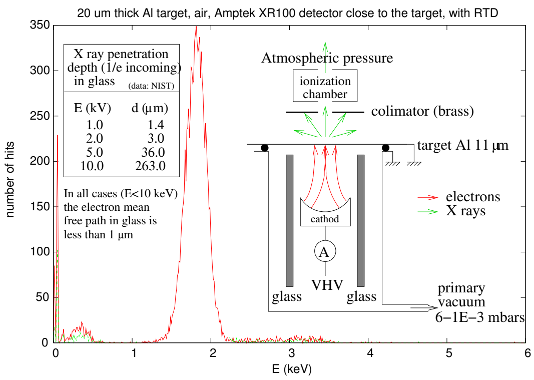
Objectives

- Analyze the influence of **soft X-rays & electrons** on **quartz acoustic resonators**
- Analyze the usability of quartz oscillators for **quantitative** ionizing radiation **dose measurements**

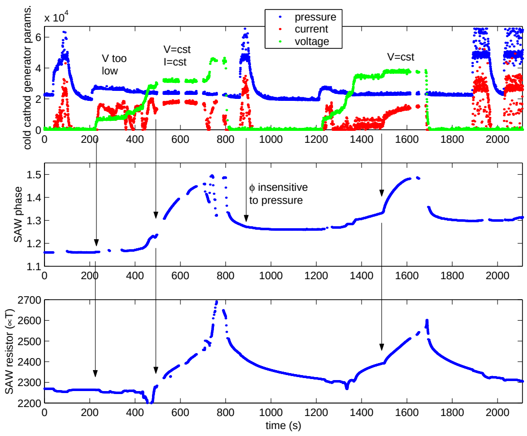
Cold-cathode X-ray generator

- a high voltage generator (0-12 kV, 0-10 mA) accelerates electrons and creates a plasma (pressure=5.10^{-2} mbars)
- the accelerated electrons hit a grounded 11 μm Al electrode
- Bremsstrahlung/ionization X-rays leak through the Al sheet (spectrum= Bremsstrahlung+absorption of low energy Xrays)
- peak energy defined by the energy of the incoming electrons (=voltage)
- these electrons propagate either in vacuum (5.10^{-2} mbars) or air, but strong absorption in air due to low energy
- calibration of the X-ray generated dose using an ionization chamber (requires the area above the target to be at room pressure)
- alternative to X-rays: accelerated electrons as ionizing radiations (requires the area above the target to be at primary vacuum pressure $\simeq 3-5\times10^{-2}$ torrs).



Schematic of the cold-cathode Xray generator and measured X-ray spectrum: the peak is the result of absorption of the low energy X rays by the Al target and air, and the upper limit is defined by the energy of the incoming electrons.

Ionizing radiation detection

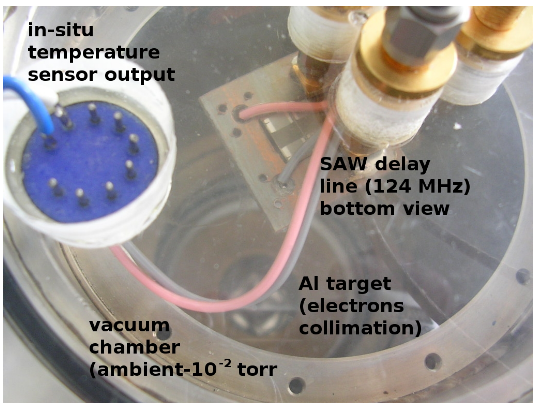


Experimental measurement of all relevant parameters of the electron generator (cathode voltage and current, vacuum chamber pressure), the phase at constant frequency ($\simeq$125 MHz) of the Love-mode delay line and AT-quartz substrate temperature through a thermistor deposited next to the interdigitated transducers.

- monitoring of the phase of a Love-mode SAW (2.2 μm SiO_2 on AT-cut quartz), $\lambda = 40$ μm, centrale frequency $\simeq$125 MHz, as well as a thin (180 nm-think) *Al* strip on the quartz substrate acting as thermistor (3.5 Ω/K, 2280 Ω at room temperature).
- no visible effect of soft X-rays on the behaviour of acoustic sensors: insufficient dose ?
- strong temperature increase of our sensor (*in-situ* measurement), up to 90 K, upon irradiation by accelerated electrons
- threshold voltage below which no effect of electron irradiation is observed (first ↓): absorption of electrons by remaining air in chamber ?
- heating correlated with strong phase shift during electron irradiation (2nd and 4th ↓)
- little effect of pressure on the behaviour of the delay line (3rd ↓)
- observation compatible with STW (505 MHz) and BAW (12 MHz) resonators

Conclusion and perspectives

- substrate heating has been identified as the cause of phase/frequency shift of our delay line/resonator used as radiation detector
- quartz based resonators/delay lines are thus used as sensitive calorimeters (heating associated with energy transfer from ionizing radiation)
- this mechanism can be enhanced to improve the sensitiviry by using Z-cut quartz as substrate (strong temperature coefficient)
- accurate calibration temperature dependence of the phase/frequency is needed to separate heating from other possible disturbances associated with ionizing radiations
- wireless interrogation is to be enhanced to be compatible with range/medium required for**therapeutic** uses of ionizing radiations



Experimental setup of the delay-line irradiated by accelerated electrons

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