ACCURATE LINEAR THERMAL EXPANSION COEFFICIENT DETERMINATION BY INTERFEROMETRY

MIKES - Metrology

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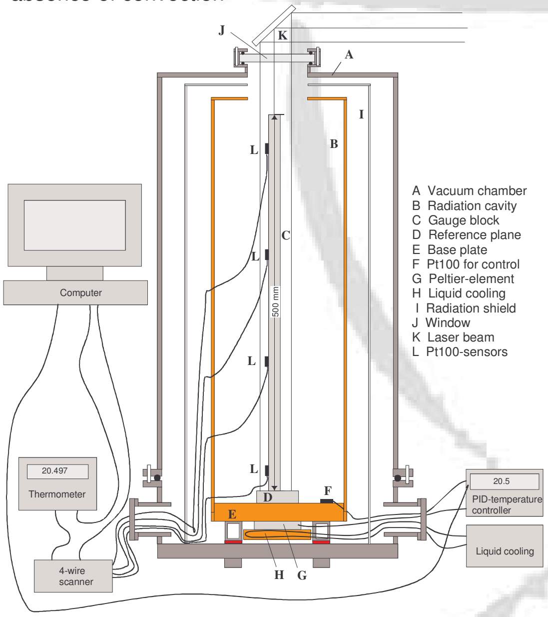
Abstract

- In precision length measurements the accurate and traceable value of the linear thermal expansion coefficient (LTEC) is needed
- A dilatometer that utilises a gauge block interferometer for relative length measurement has been constructed
- Standard uncertainty of 0,02 × 10-6 1/K for LTEC of gauge block has been reached

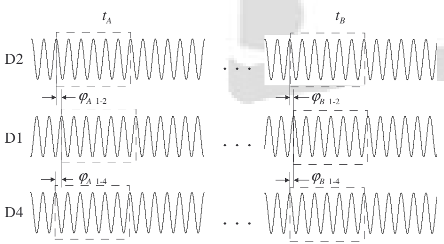
Instrument composition

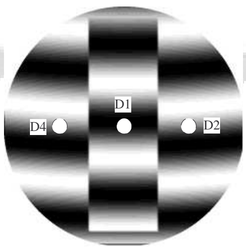
- The main solution is to measure the lengthening of a sample by interferometry in a vacuum
- A vacuum environment was selected due to its easiness with a refractive index of medium (*n*) determination
- The problem with a vacuum solution is that thermal stabilisation times of samples are longer due to the absence of convection



- The measurement of phase difference between the gauge block surface and the reference platen is repeated at proper intervals in order to follow number of full periods
- The simulated interferogram of static state of the gauge block interferometer and phase difference measurement principle are illustrated below.

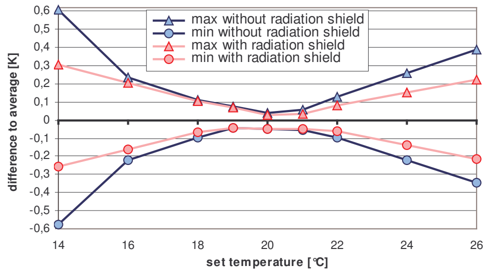
$$\Delta L = \left(\frac{\varphi_{B1-2}+\varphi_{B1-4}}{2} - \frac{\varphi_{A1-2}+\varphi_{A1-4}}{2}\right)\frac{\lambda}{4\pi}$$



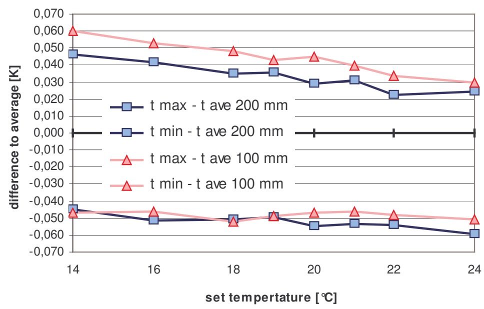


Temperature control and measurements

- In order to allow fast operation and minimise temperature differences, the radiation cavity was constructed of copper
- A radiation shield is placed between the cavity and the chamber wall
- The temperature is set by changing the temperature of a base plate with two peltier elements (electric power 150 W)
- Temperature gradients inside the cavity were studied by connecting 4 Pt100 sensors at different heights and setting the controller from 14 to 24℃



- The temperature of the sample is measured with four calibrated Pt100 sensors and a thermometer
- When the temperature differences of sensors no longer diminish, the relative expansion is measured and recorded together with the temperature values
- Typical temperature gradients in a 100 mm and 200 mm steel gauge blocks are illustrated here



Uncertainty

The model of LTEC measurement for analysis of the uncertainty can be expressed as follows:

$$\alpha = \frac{1}{L}\frac{\Delta L + \delta l_P}{\Delta T + \delta t_g}$$

where δl_p is the correction to compensate for the non-linearity of the interferometer and δt_g is the correction due to the temperature differences of the gauge block

Quantity	Standard uncertainty	Probability distribution	Sensitivity coefficient	Standard uncertainty $\times 10^{-6}$ 1/K
L	2 µm	normal	$-5{,}5\times10^{-5}$ m^{-1} K^{-1}	0,00011
ΔL	0,001 µm	normal	5 m^{-1} K^{-1}	0,005
δl_p	0,001 µm	rectangular	5 m^{-1} K^{-1}	0,005
ΔT	4 mK	normal	$-2{,}75\times10^{-6}$ K^{-2}	0,011
δt_g	5 mK	normal	$-2{,}75\times10^{-6}$ K^{-2}	0,014
Total	L=100 mm			0,021

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