Leica Absolute Distance Meter

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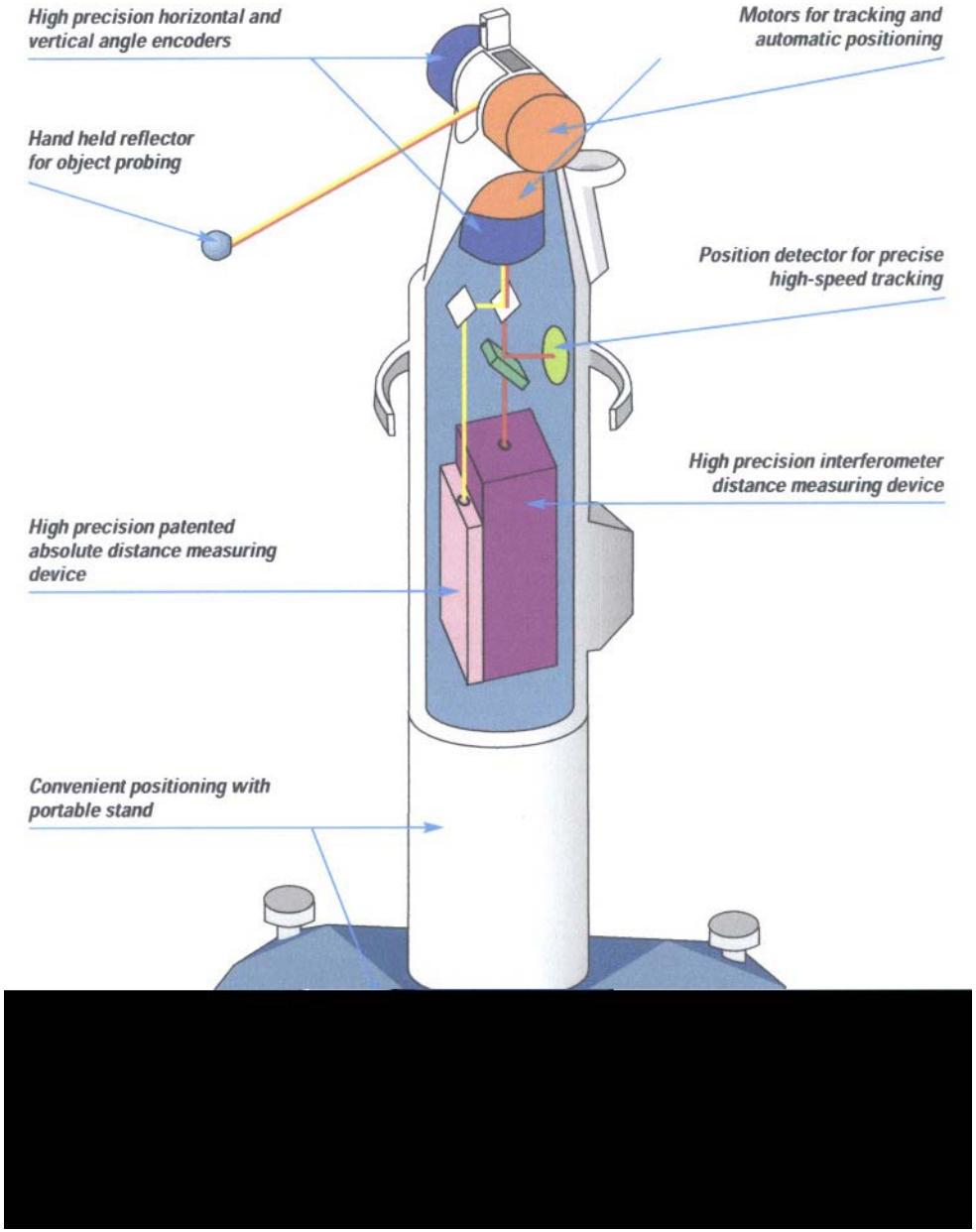
Leica Disto-Pro ranging device

- Used during SBMD and NMSD tests for radius of curvature measurements.
- Time of flight ranging device.
- +/- 2mm accuracy.
- 1.5 to 50 meters range.
- Works best with diffuse targets.
- Compact.
- Inexpensive.

Requirements for measuring AMSD radius of curvature

- Remote measurement device to be located at or near ROC.
- Absolute distance measurement or ranging device.
- 1 micron measurement resolution.
- Better than 25 microns measurement accuracy.
- Better than 25 microns measurement repeatability.
- Greater than 50 meters range.
- Specular surface and corner cube.
- Fast sample rate.
- Compact.
- Easy to use.

Leica laser tracker



CPU, power supply, and ADM

ADM on hexapod

Ranging system principle

Distance D, is determined by measuring the phase angle between the transmitted sine wave and the received sine wave.

The relationship between phase angle ϕ_r ,time delay t_r ,and modulation frequency f_0 ,is:

$$t_r = \phi_r / 2\pi f_0$$

$$D = C\, t_r / 2 = C\, \phi_r / 4\pi f_0$$

$$D_0 = N_0 C / 2 f_0$$

ADM description

IR laser diode 780nm (1mW max output)

Visible laser diode for pointing

Polarization modulation

External modulation with $LiTaO_3$ crystal @700-900 MHz

Differential signal detection

Detection of the same signal (same phase position)

Frequency Shift ==> 0° Phase

Minimal measurement distance 1.5 m due to minimum bandwidth of 150 MHz

Maximum measurement range 50 m

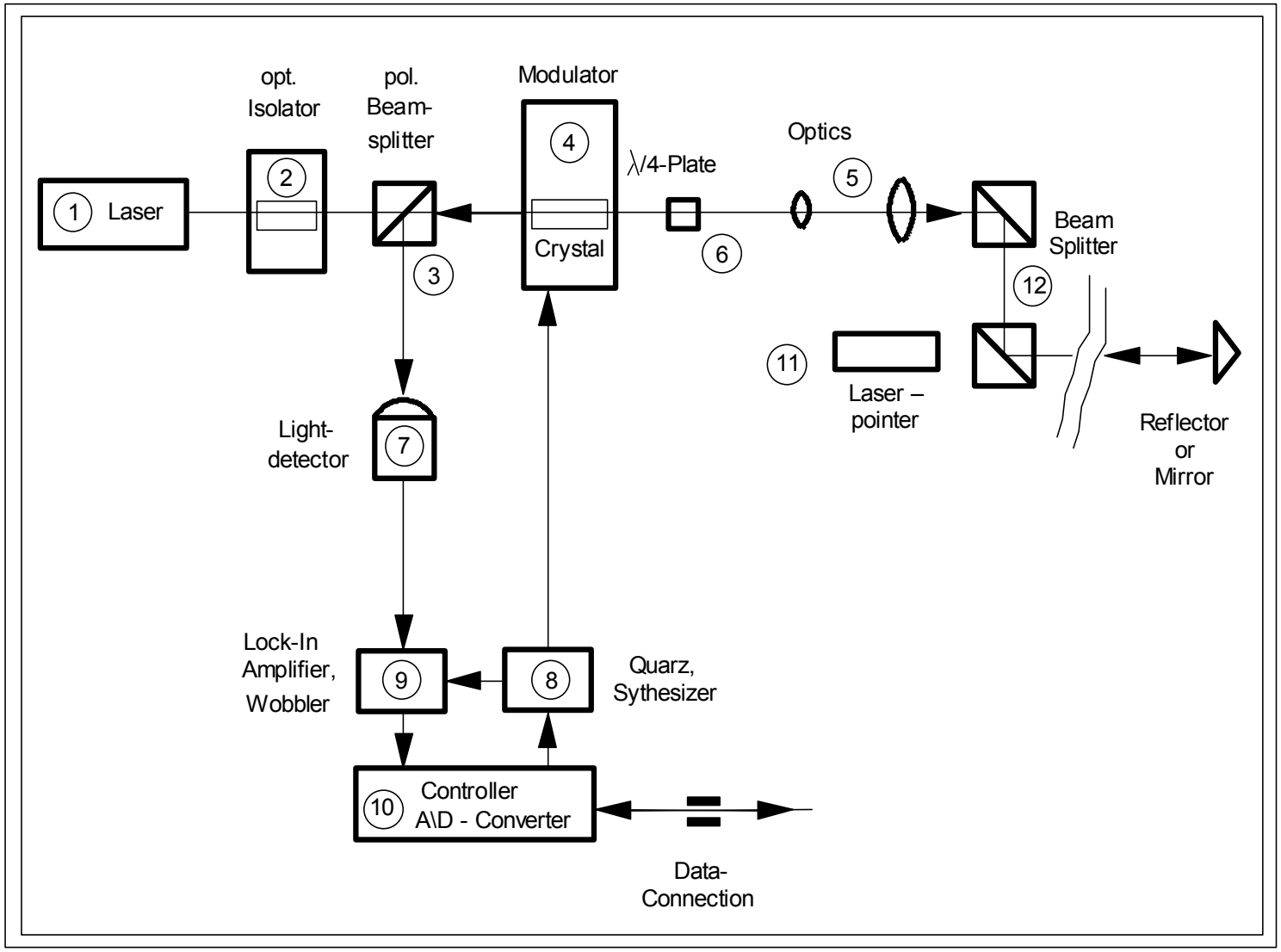
Distance measurement resolution 1 µm

Distance measurement accuracy better than 50 µm.

400 x 120 x 40 mm (L x H x T)

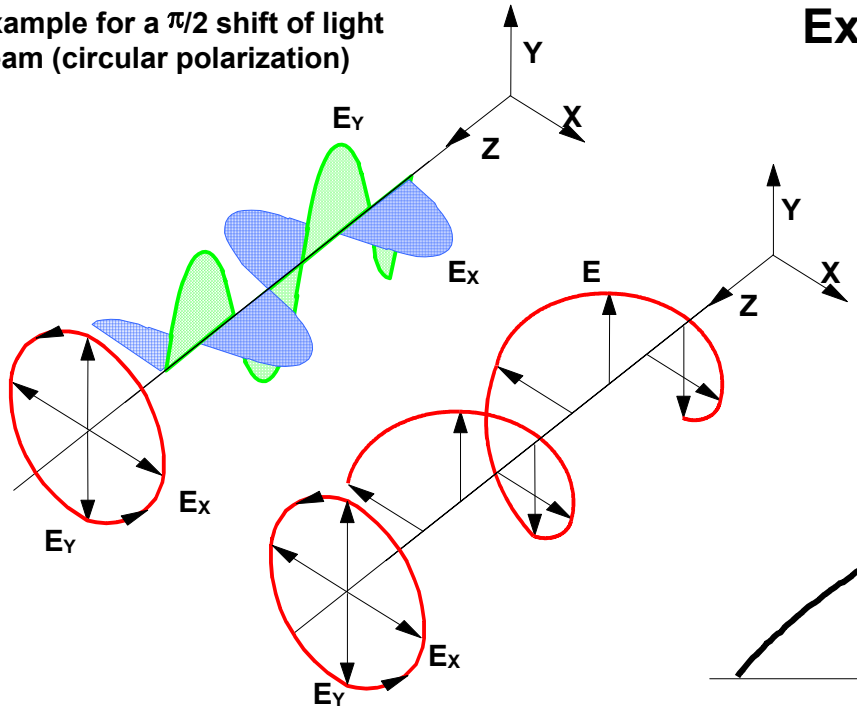
2 kg

ADM schematic



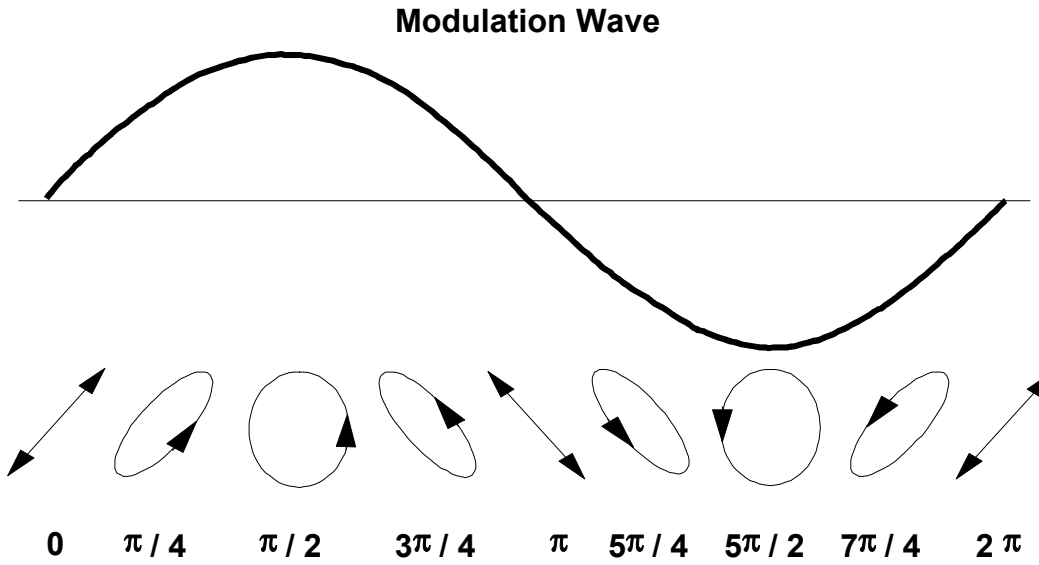
ADM - Modulation methods

Example for a π/2 shift of light beam (circular polarization)



External modulation with $LiTaO_3$ crystal

- not directly influencing the laser
- using non linearity effects
- beam velocity is different at different axis E_X and E_Y

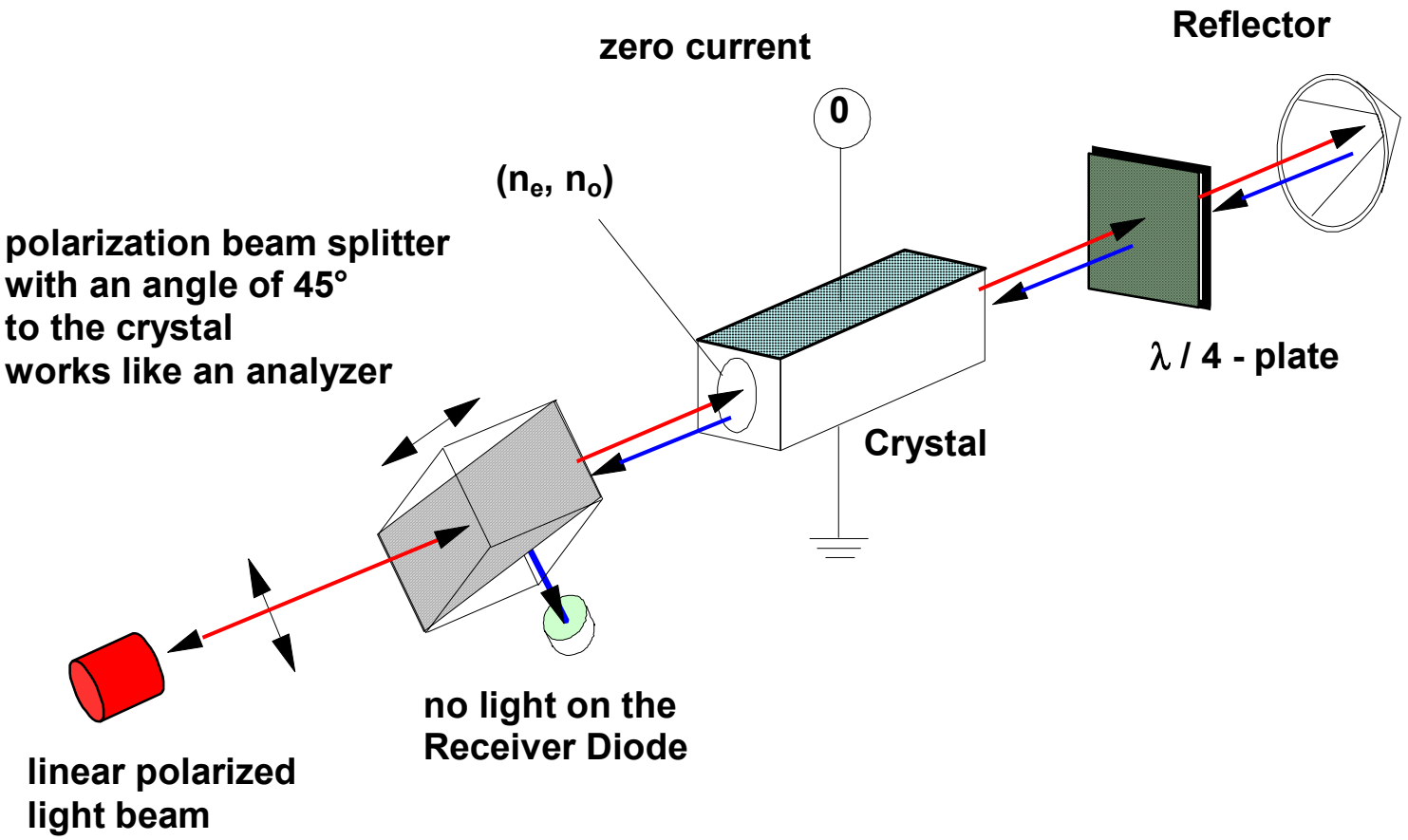


Polarization Modulation

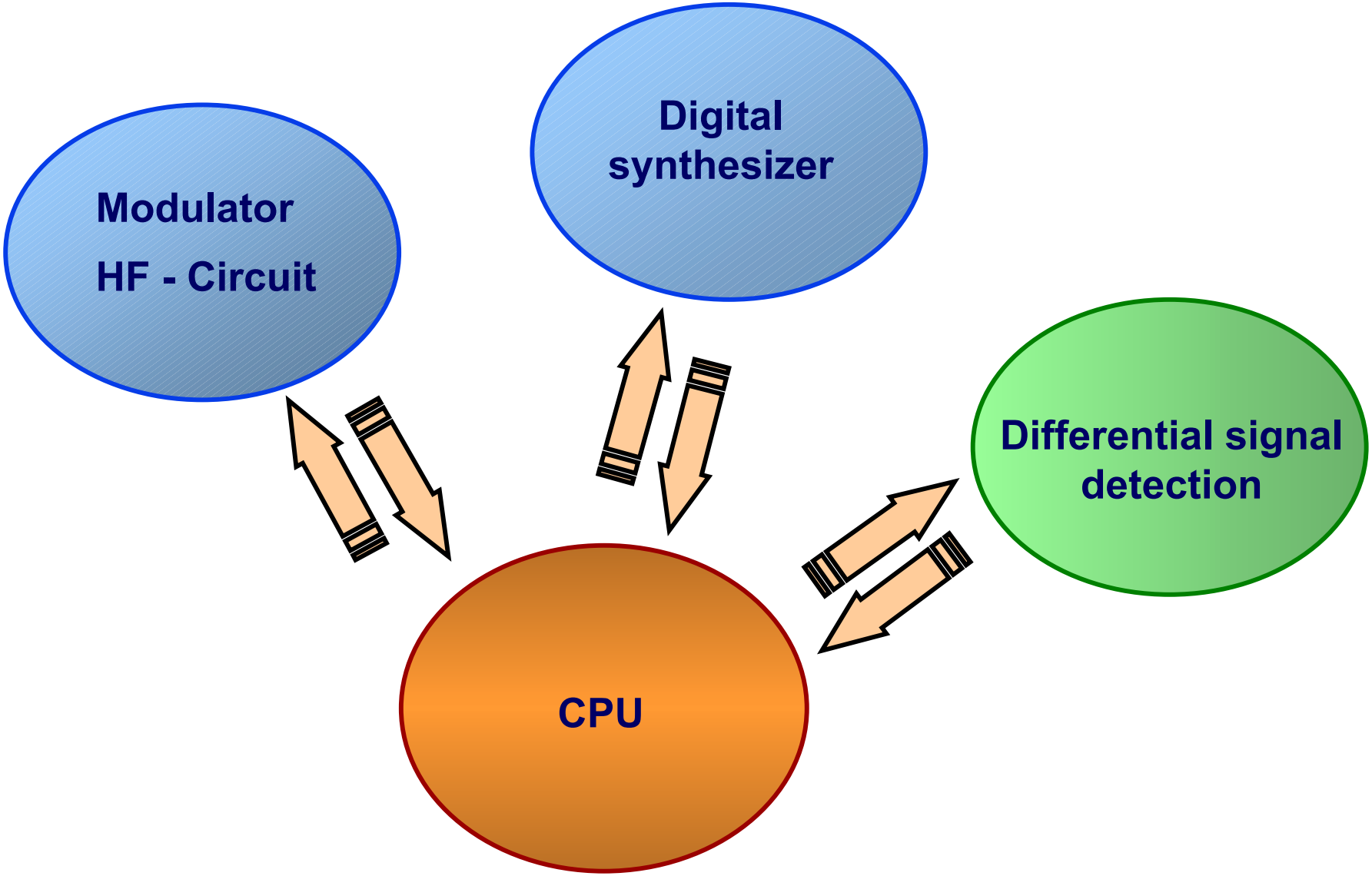
systematical change of the beam shift by an electronic oscillation circuit

high frequency 700 - 900 MHz

ADM - Beam Pass and Phase Control



Overview - Major Functionality Blocks

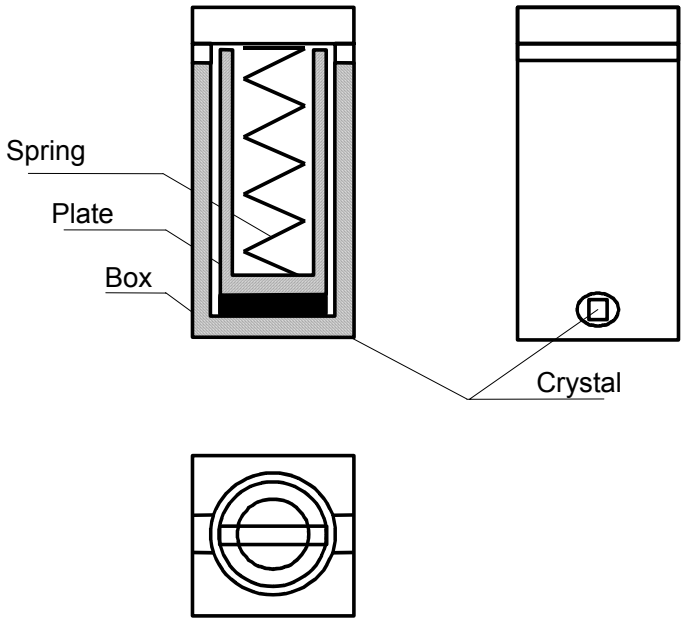


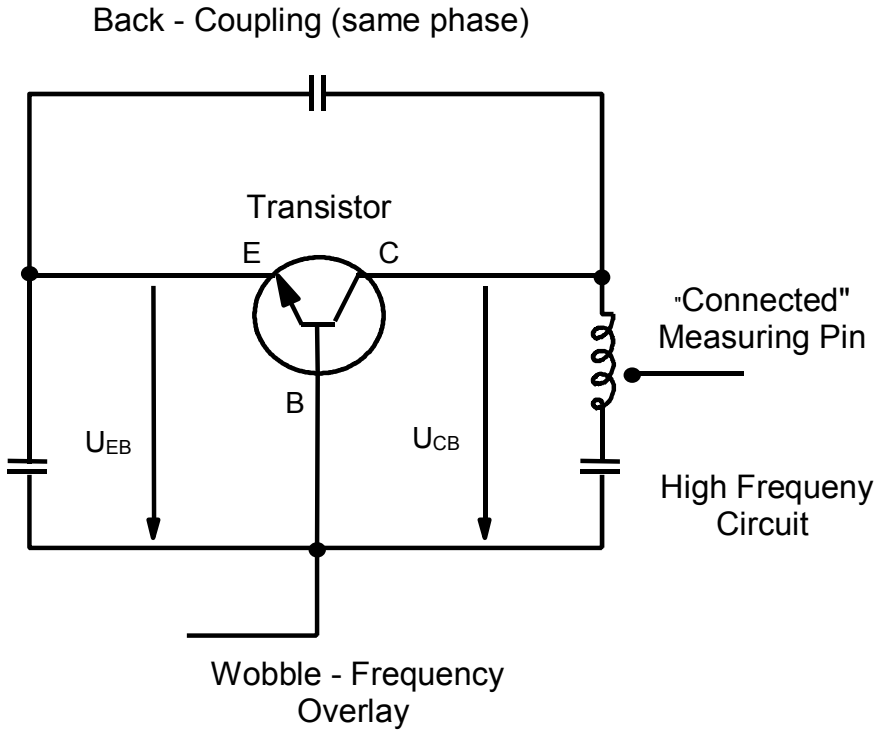
Modulator - High Frequency Circuit

Systematical influencing of the refraction indices n_e and n_o of the crystal

High frequency with enough power

Optimized modulation voltage ==> enough modulation strength



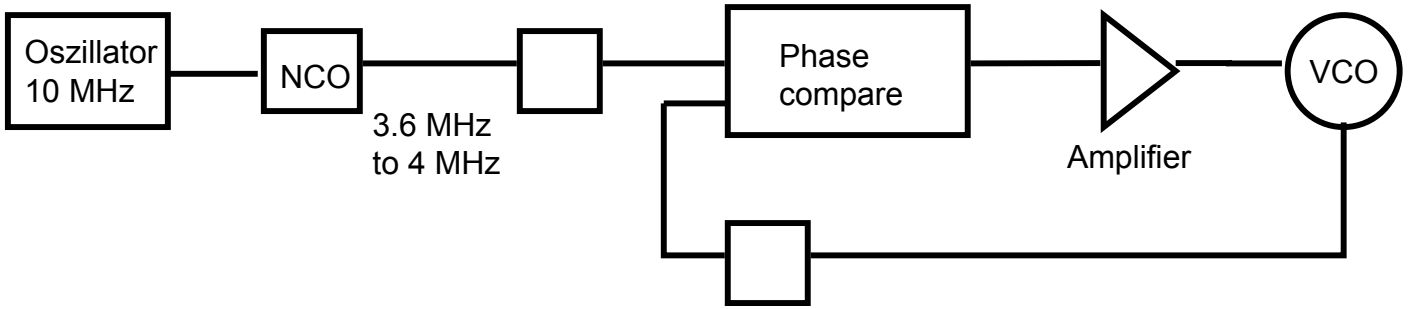


Digital synthesizer

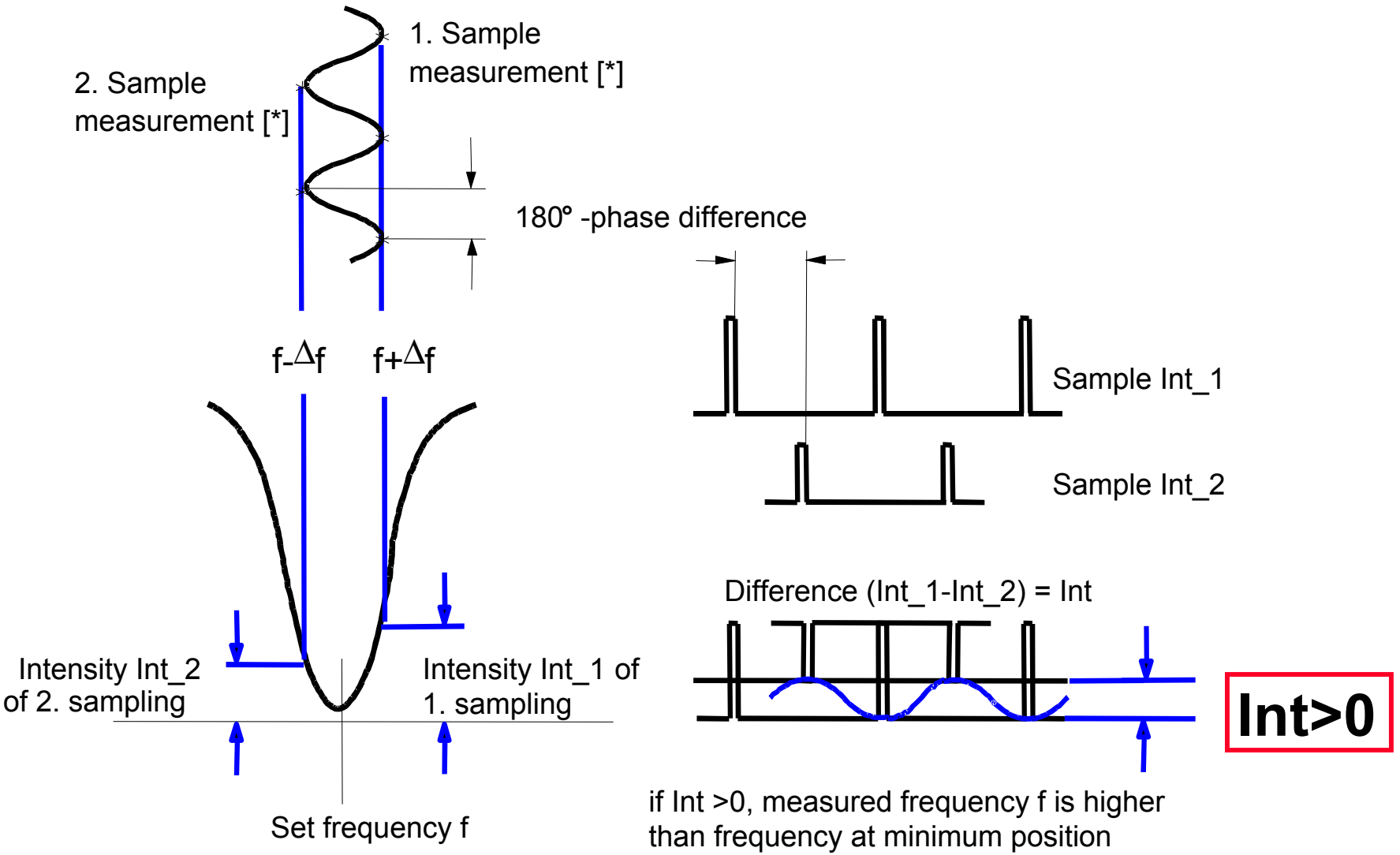
Synthesizer for flexible and defined frequency movement

Very short reaction time

Very small frequency steps (system resolution)

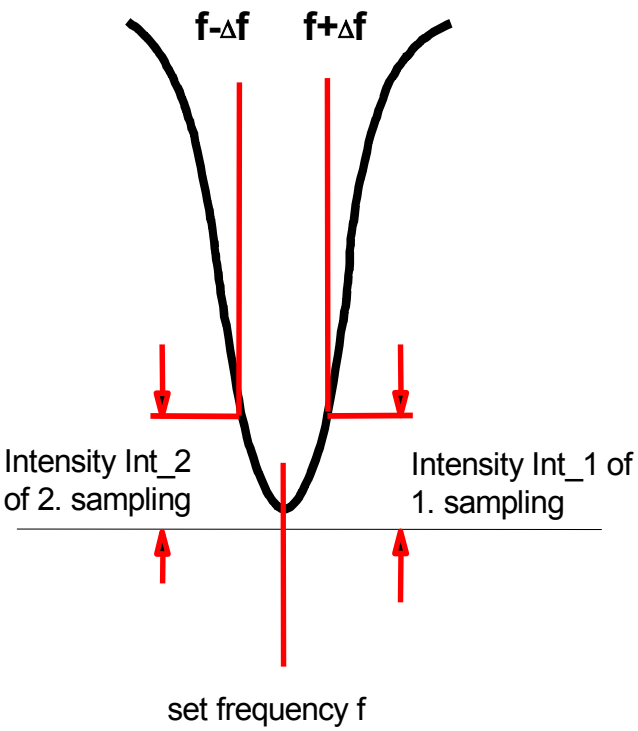


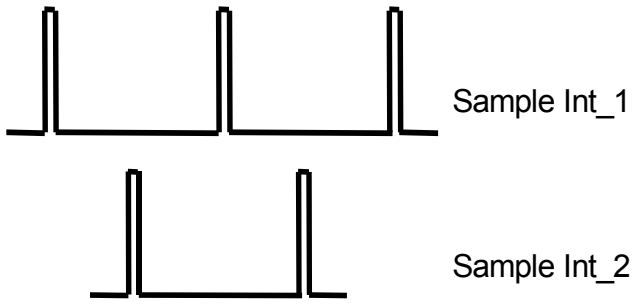
ADM - Differential Signal Detection



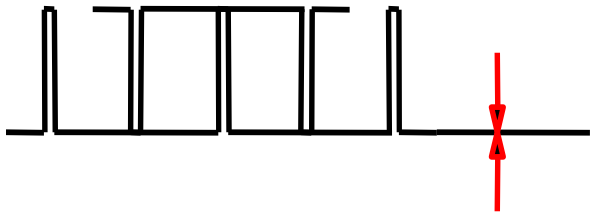
if Int >0, measured frequency f is higher than frequency at minimum position

ADM - Differential Signal Detection





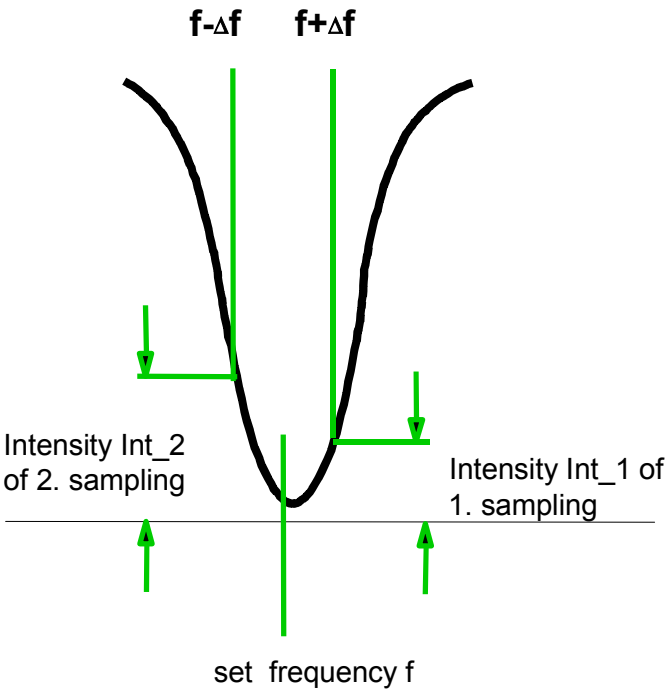
Difference (Int_1-Int_2) = Int

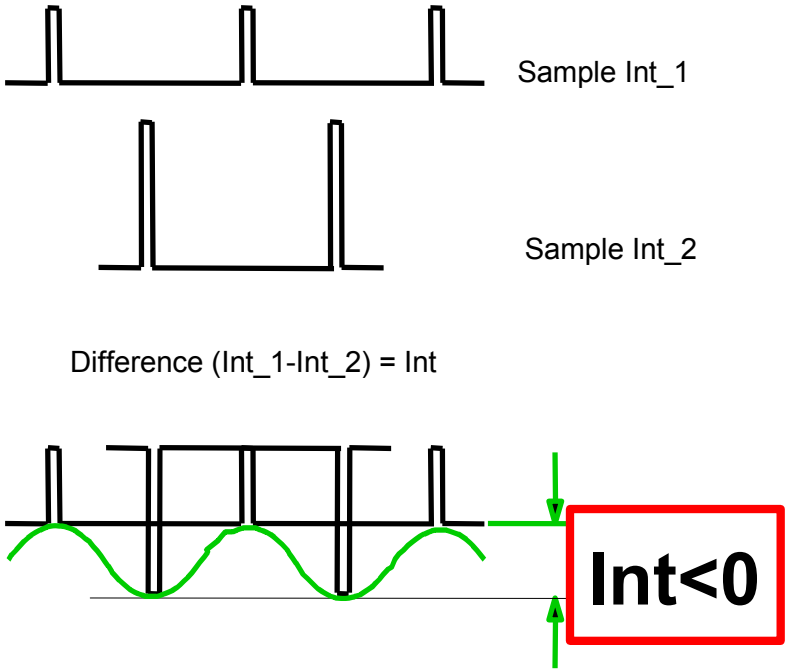


Int=0

if Int = 0, frequency f is set
to minimum position

ADM - Differential Signal Detection

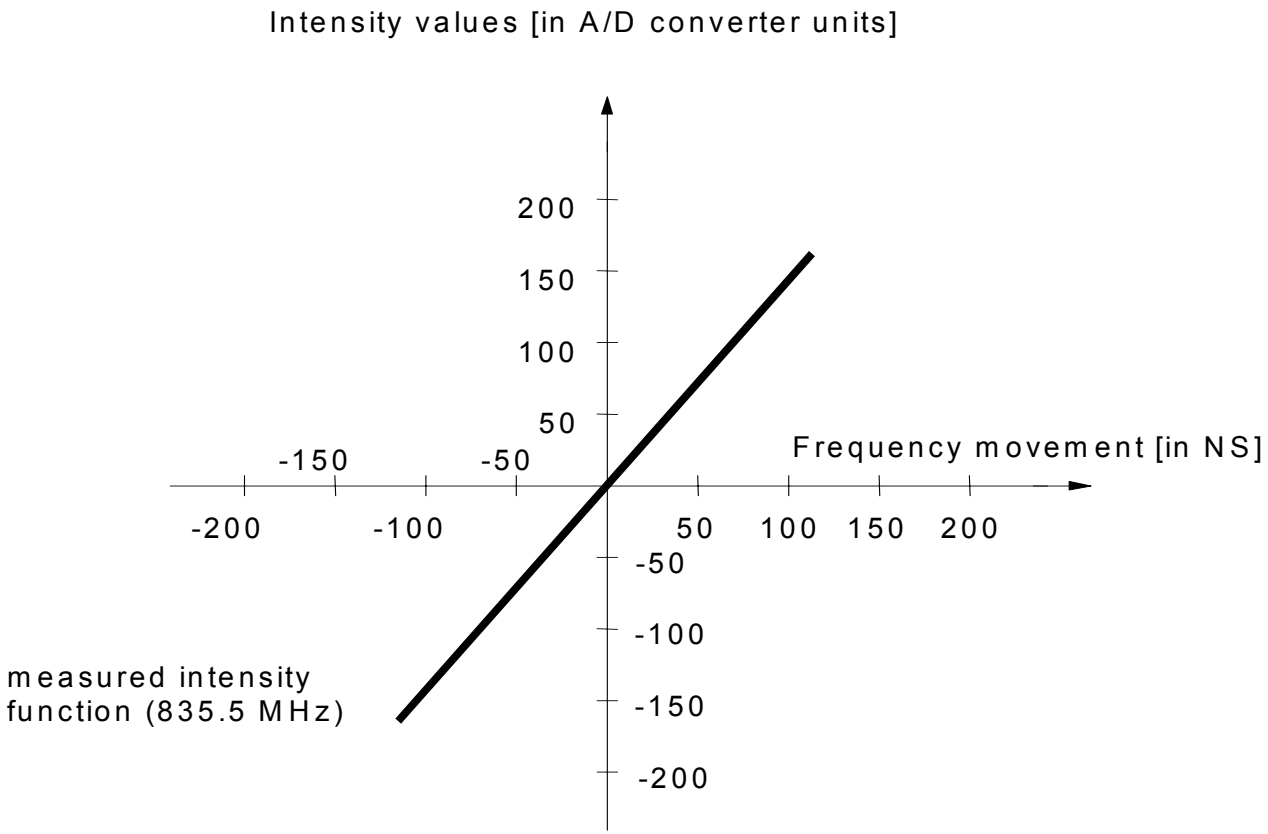




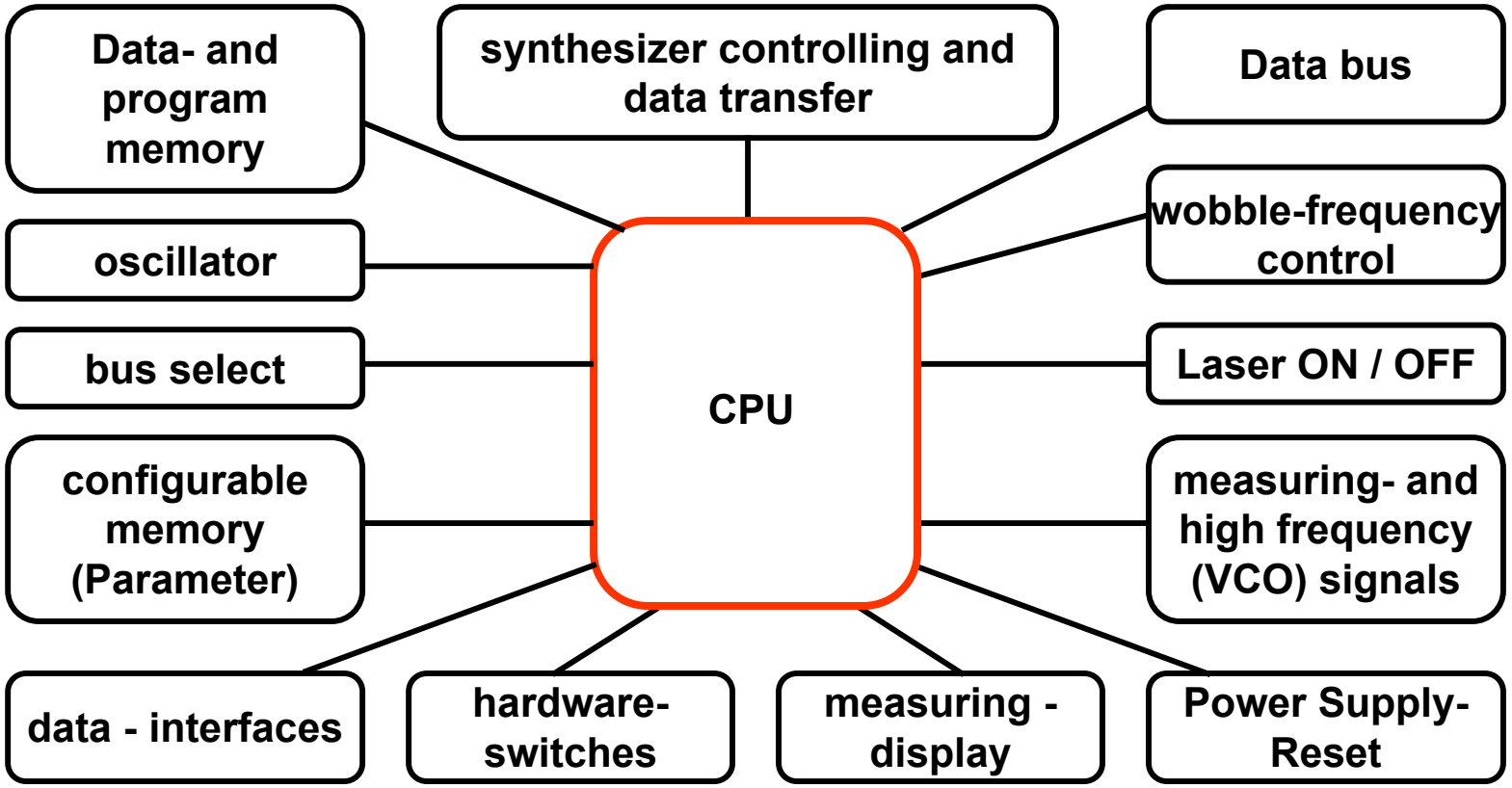
if Int < 0, measured frequency f is smaller than frequency at minimum position

Sampling along a Minimum Position

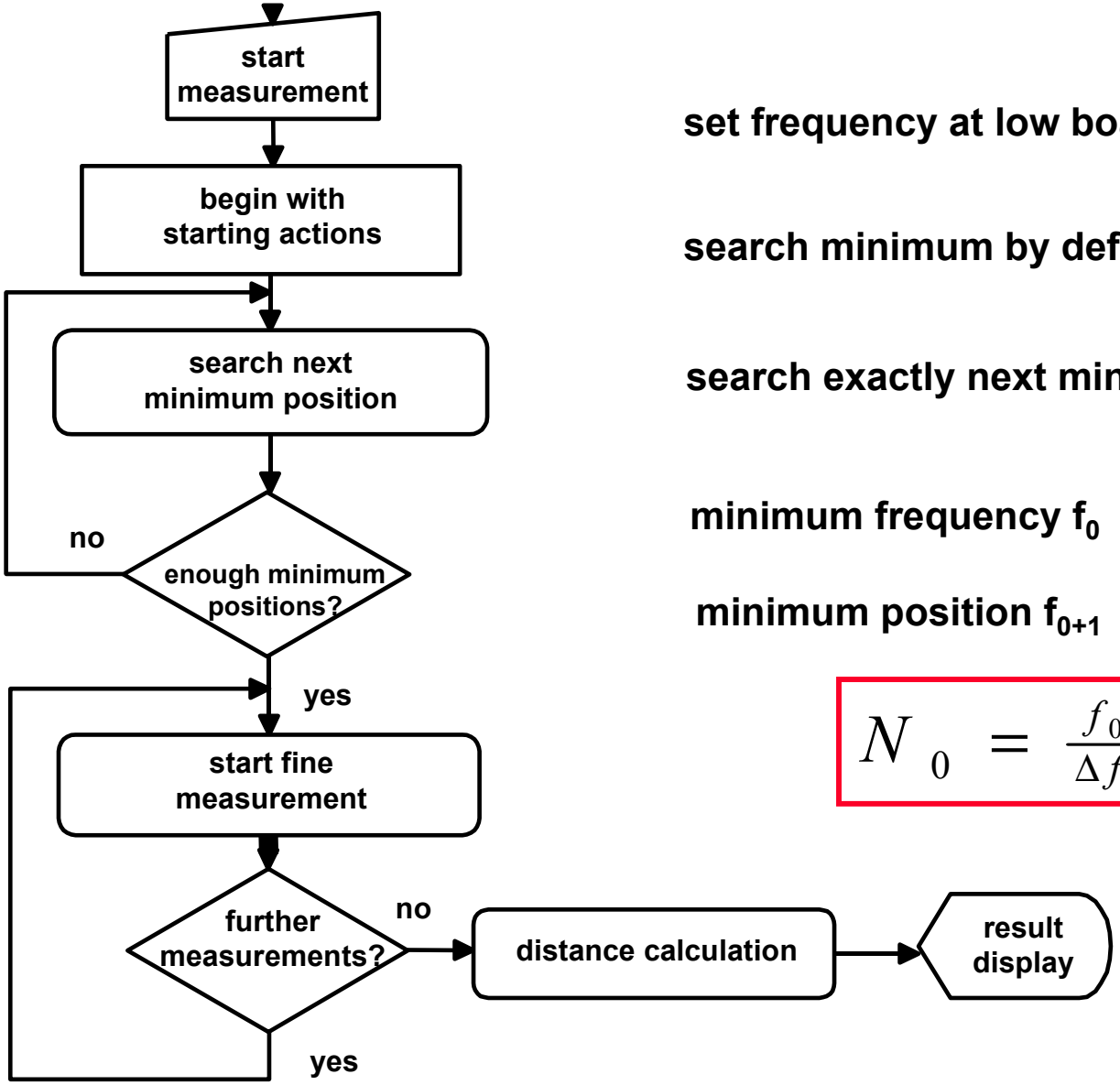
Using difference method to sample along a minimum position, the intensity values will follow a line



Micro - Controller Functionality



Measurement flow and distance calculation



set frequency at low boarder of modulation band

search minimum by defined frequency movement

search exactly next minimum position

minimum frequency f_0

minimum position f_{0+1}

$$\Delta f = f_{0+1} - f_0$$

$$N_0 = \frac{f_0}{\Delta f} \quad \text{or} \quad N_1 = \frac{f_1}{\Delta f}$$

$$D_0 = \frac{N_0 \cdot c}{2 \cdot f_0}$$

Atmospheric Influence

Accuracy depends on refractive index of air between the ADM and the target.

Refractive Index

- **T = air temperature in degrees Celsius**
- **P = pressure in millimeters of Mercury**
- **R = relative humidity in percent**

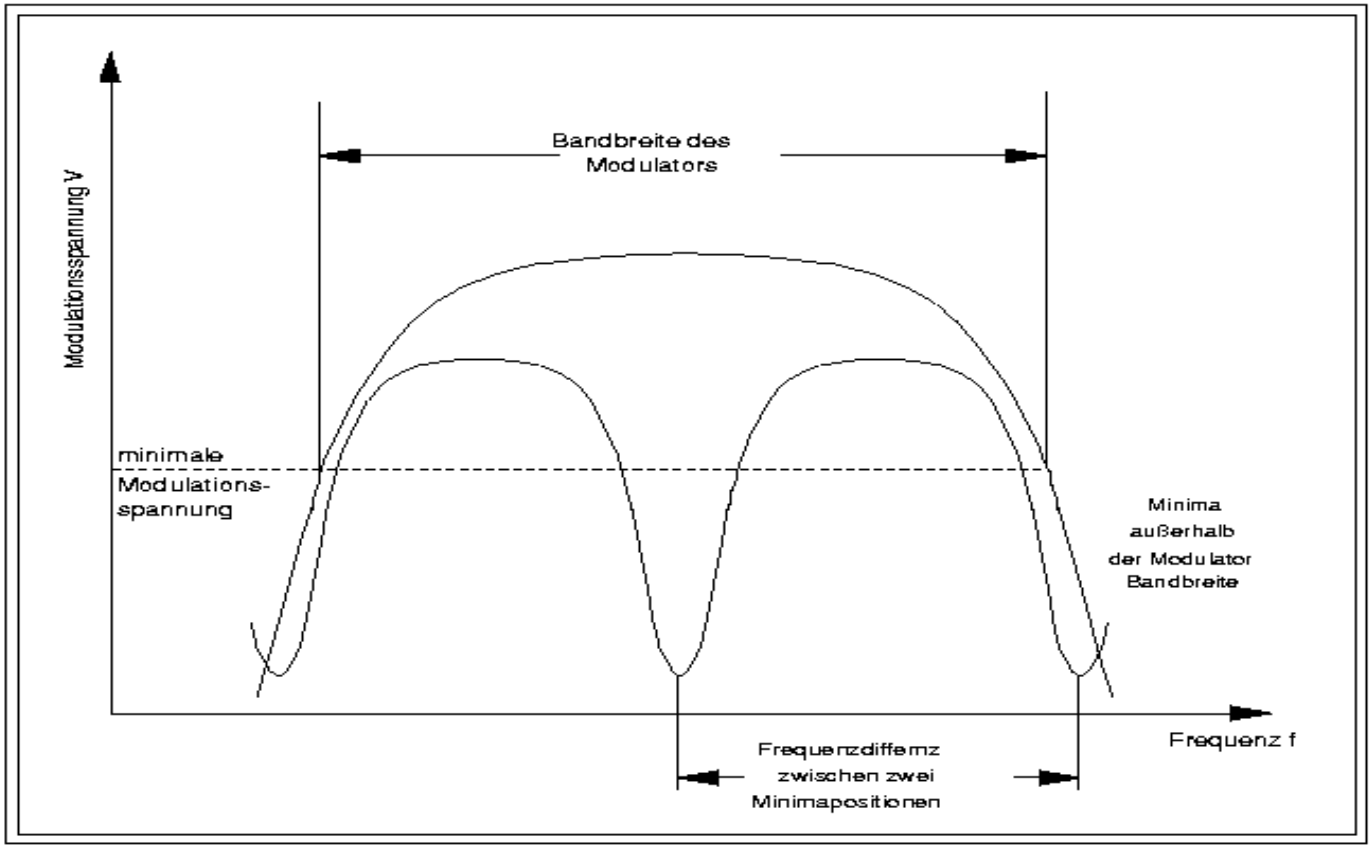
$$N_{Gr} = 0.3889479 \cdot P \cdot \left[\frac{1 + 10^{-6} \cdot P \cdot (0.817 - 0.0133 \cdot T)}{1 + 0.0036610 \cdot T} \right] - 556.68 \cdot 10^{-6} \cdot R \cdot 10^{\frac{7.5 \cdot T}{T + 237.3} + 0.6609}$$

Shortest Distance

Limitations are related to:

Bandwidth of the modulator of 150 MHz

Modulation frequency



ADM measurement output

ADM Measurement

Refraction = 1.00027529886

A = -49849.000000

Dist. [m]	C	K [um]	P [um]	f [Hz]	M [m]	SD [um]
20.465532	124	-3	2	840019528	20.465532	0.000000000
20.465532	124	0	1	840019472	20.465532	0.000000000
20.465534	125	-1	2	840019472	20.465532	1.168007728
20.465534	124	-1	2	840019472	20.465533	1.168007728
20.465534	124	-1	2	840019472	20.465533	1.118282261
20.465532	123	-3	2	840019528	20.465533	1.087356019
20.465532	123	-3	2	840019528	20.465532	1.066240300
20.465534	124	0	2	840019416	20.465533	1.081365031
20.465534	123	-1	1	840019472	20.465533	1.092571186
20.465534	124	0	2	840019416	20.465533	1.054326627
20.465534	124	0	2	840019416	20.465533	1.000222061
20.465534	124	0	2	840019416	20.465533	0.996080337

Acceptance test methods

Repeatability test

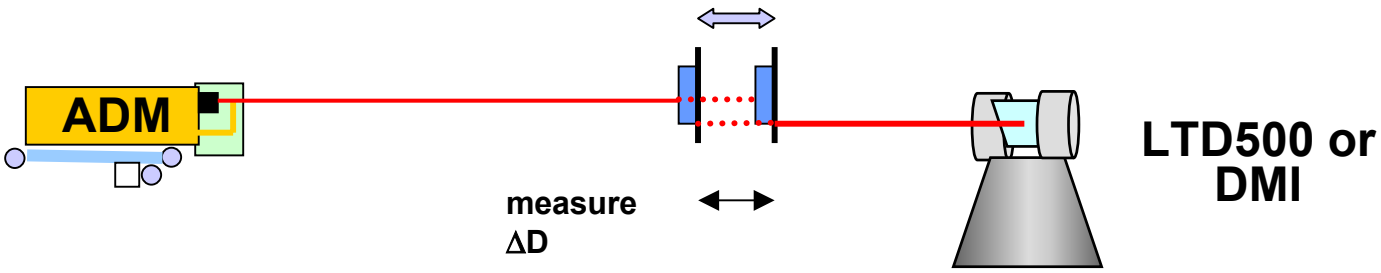
S.D. of 30 measurements to a corner cube <25 um

S.D. of 30 measurements to a mirror <50 um

Relative accuracy test

20 distance measurements to a corner cube, compare distance with LTD500, deviation ΔD <25 um

20 distance measurements to a mirror, compare distance with LTD500, deviation ΔD <50 um



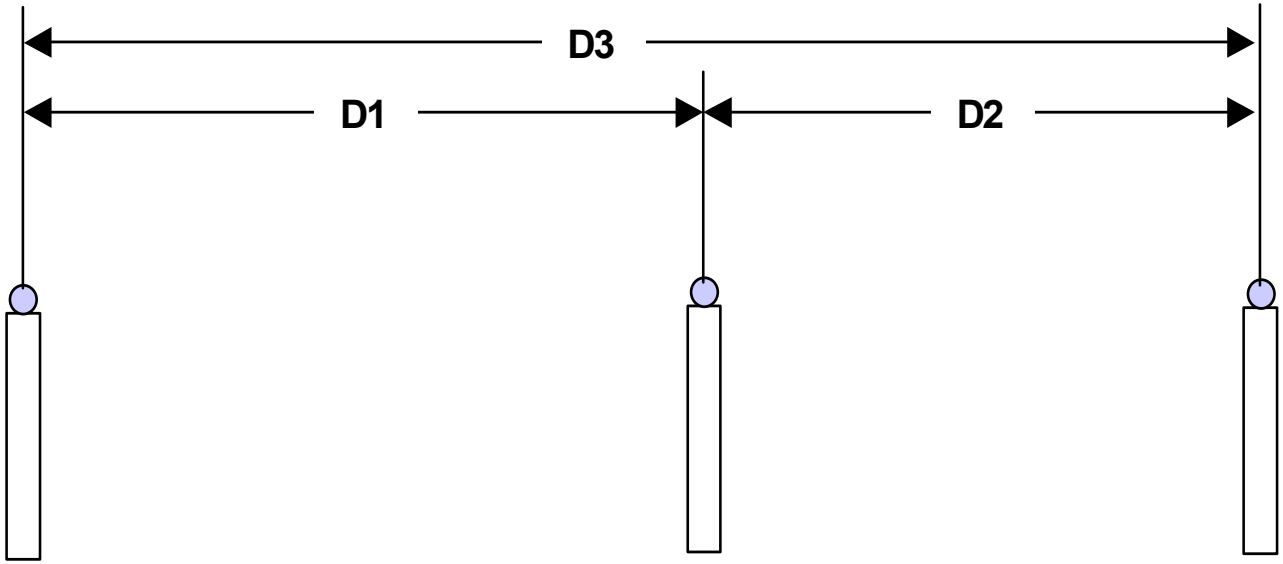
Acceptance test methods (continue)

ADM offset determination (LTD500 required)

3 distances to be measured from both directions with LTD500

3 distances to be measured from both directions with ADM

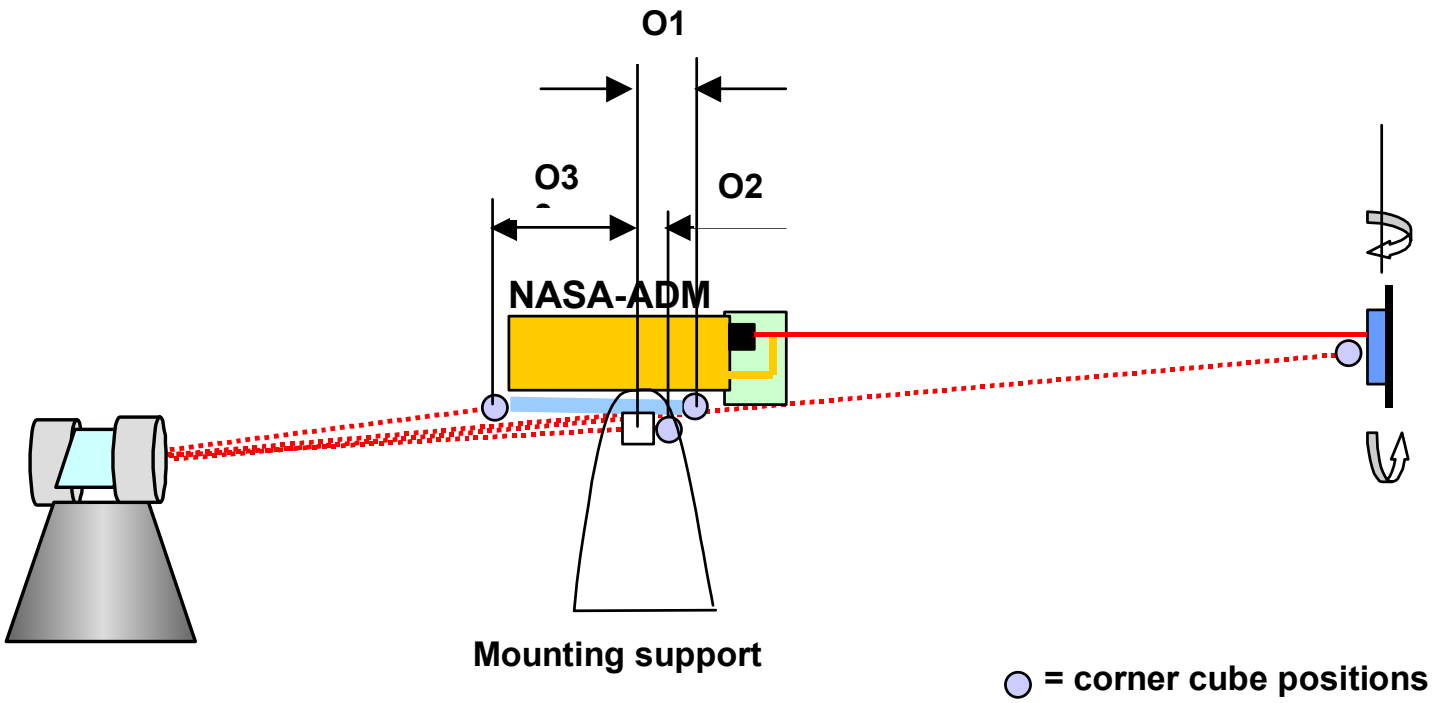
Deviation between (D1 + D2) and D3 < 35 um



Acceptance test methods (continue)

Absolute distance accuracy test (LTD500 required)

- Measure 3 distances between 3 points with LTD500
- Measure 3 distances between 3 points with ADM
- Deviation between (D1 + D2) and D3 < 35 um



Acceptance test results

	Requirements	ADM s/n 166	ADM s/n 406
Repeatability to corner cube	S.D. < 25 um	< 1.3	< 1.8
Repeatability to mirror	S.D. < 50 um	< 3.5	< 2.7
Relative accuracy to corner cube	ΔD < 25 um	< 1.1	< 1.8
Relative accuracy to mirror	ΔD < 50 um	< 19	< 35
Absolute distance accuracy	ΔD < 35 um	< 21	< 36

Conclusions

ADM measurements are very accurate and repeatable for corner cubes.

Performed cryo deformation test of Gr-Ep reaction structure with ADM.

Software interface is easy to use.

May have problem measuring to Be mirror due to polarization properties or scatter.

Currently have no method to calibrate the ADM in house.

Demo is available on Friday during tour at XRCF. Demonstrate relative accuracy with a HP DMI.