Automatic Height Determination

On the Way to Digital Levelling

The forerunners

Basics (configuration ,numerical and optical codes)

Image processing

The individual Solutions (Leica, Sokkia,Topcon, Trimble (Zeiss), FOIF)

Performances

geomETH


Developments and Patents

- 1966 — Nivellier mit digitaler Anzeige (UNI Bonn)
- 1976 — Sagem (Patentschrift)
- 1978 — Thomson (Patentschrift)
- 1984 — Messeinrichtung zur Erfassung der Relativposition zwischen zwei Teilen (WILD Heerbrugg). (Patentschrift)
- 1985 — Längenmessverfahren (TU Dresden, Zeiss Jena) (Patentschrift)
- 1988 — Anordnung zur Höhenmessung (Zeiss Jena) (Patentschrift)
- 1990 — Wild NA2000
- 1990 — Measuring a Difference in Elevation (Optec, Japan) (Patentschrift)
- 1992 — Wild NA3000
- 1994 — Zeiss DiNi10/20 und Topcon DL 100
- 1998 — Sokkia
- 2003 — Leica DNA 03/10 Baureihe
- 2004 — Neue Trimble Baureihe auf Basis DINI (Zeiss)
- 2004 — Leica Sprinter
- 2007 — Chinesisches Digitalnivellier
- 2009 — Sokkia/Topcon SDL1X

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Categorisation of Electronic Levels

geomETH

Active Systems

Rotationslaser   Diode line
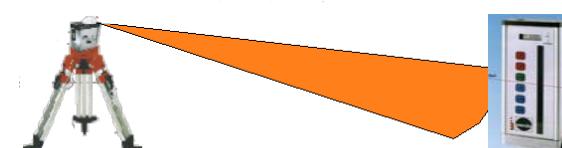
geomETH

The Priciple of the „Bonn" Digital Level
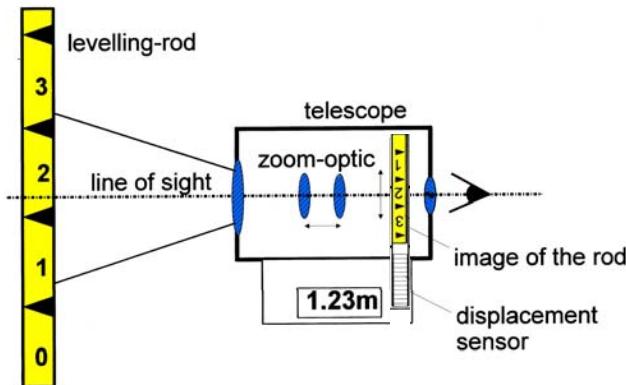
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The semi-automatisated„Bonn" Digital Level (1970)
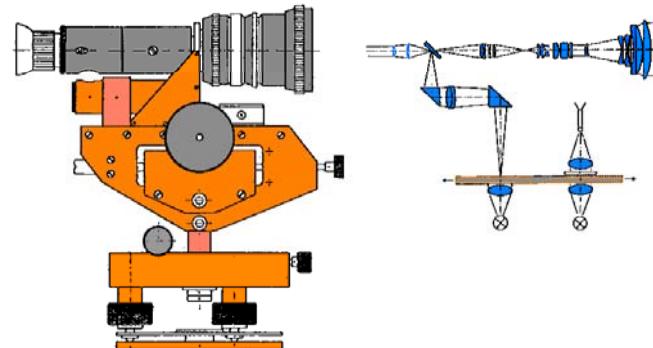
Geodätische Messtechnik - Prof. Dr. H. Ingensand ETH Zürich

Das Bonner Nivellier

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The Dresden/Jena Digital Level (1982)
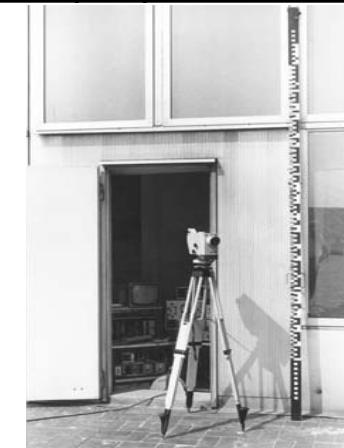
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Inside the Zeiss Ni002 DL Prototype

Fig. 1

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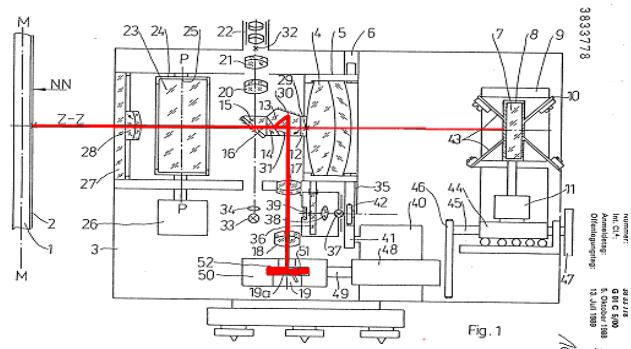
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Today's Digital Levels

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Basic configuration of DL
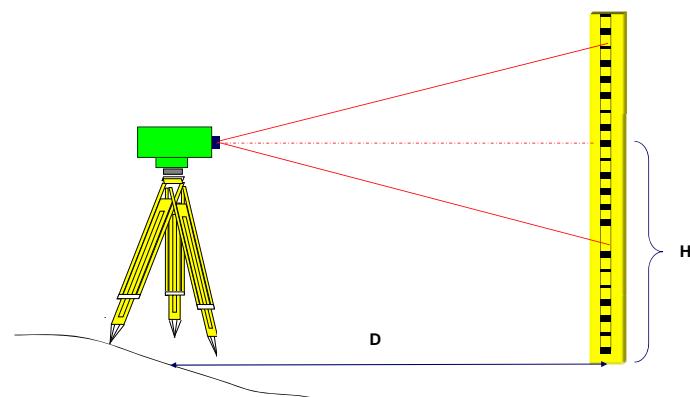
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General Design
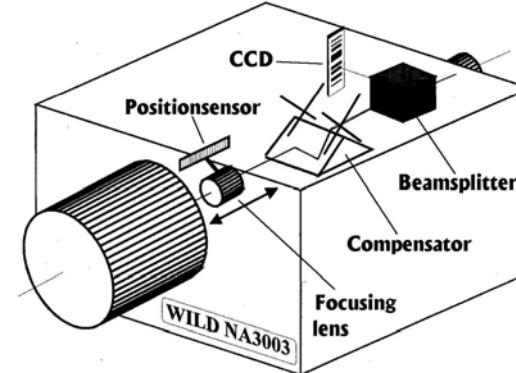
geomETH

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Image Processing in Digital Levels

A/D

OPERATING SW
APPLICATION SW

µP

123. 456
47. 4

OBJECT	CCD CAMERA	IMAGE	PREPROCESSING	MAN-
STAFF		- A/D CONVERSION	DATA REDUCTION	MACHINE-
			FINAL IMAGE PROCESSING	INTERFACE
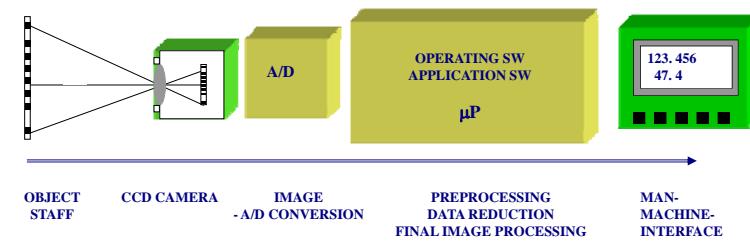
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The Information Transfer in DL

Noise

Source

Coding
Biphasen
Amplituden
Polarisation

Channel

Decoding

Sink

Atmosphere
Vibrations

Vertical
Position

Light
- artificial
- natural

Image
processing

1.784 m
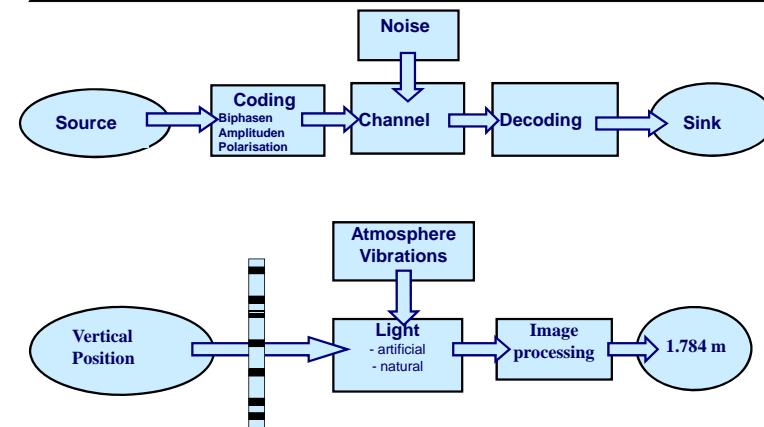
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Digitales Nivellier als Messsystem

Beleuchtung

Kompensator Optik

Refraktion
und
Turbulenz

Atmosphäre

Code

CCD-Array

Temperatureinfluss

N i v e l l i e r

L a t t e

Auswertung (d,h)

y

M e s s w e r t

Woschitz/Brunner
2001
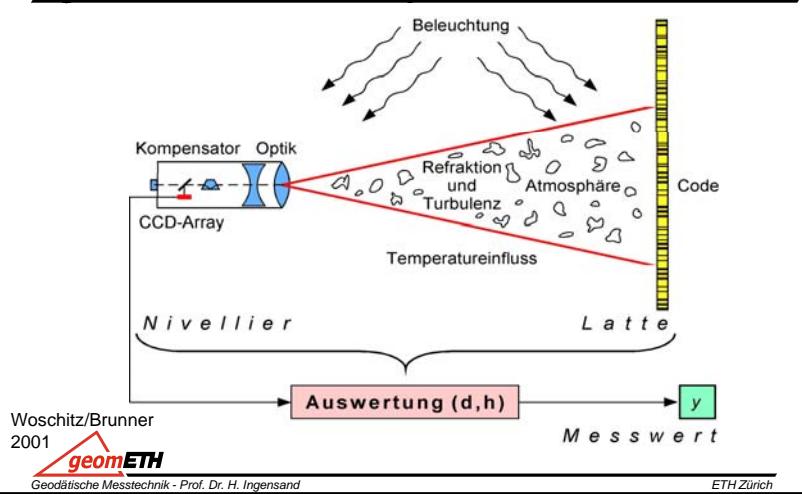
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NOISE

Illumination	Atmospheric influences	Mechanical influences	Instrumental behaviour
Various light intensity of natural light (SNR)	Turbulences (blurred image, higher SNR)	Vibrations (deviation of the line of sight)	Thermal effects (deviation of the line of sight)
Inhomogeneous light intensity by shadows at the staff	Refraction (deviation of the line of sight)	Settlement of the instrument and staff	Interference of code-element size and pixels (wrong results at certain distances)
Spectrum of the light source		Staff centring and inclination of the staff	Compensator function (eigenfrequency)

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Optimisation of DL Codes Properties

➢ 1. Numerical Code   Pseudo-stochastic, redundant, un-ambiguous,
                         According to the Staff Length (0-4 m). Fast Decoding
                         Patents of the Competitors

➢ 2.Optical Code   Optimal Resolution as a Function of the Distance and
                      the resolution of the Optics and CCD
                      Safe against Noise Influences as: Turbulence, Blur,
                      Image Distortions,……

                      Near field- , Far field Code
                      Optical Coding Possible
                      (Analog or digital Width Variation, Bi-Phase,..)
                      Patents of the Competitors

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Overview of the Various Optical Codes in DL

geomETH
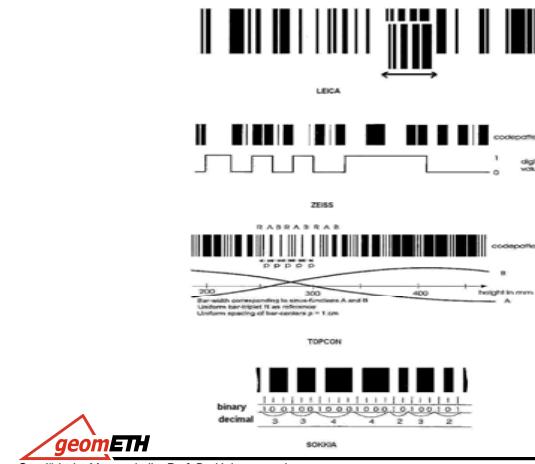
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Similarities of Geodetic Calculation Procedures (Coding-Decoding)

Technique	Digital levels	EDM	GPS
Biphase Modulation	X	X	X
Correlation	X	X	X
FFT	X	X	

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Code Properties

Manufacturer	Properties	Near-farfield code	Distance/ scale required	Dimension of one code element
Leica	Pseudostochastic	Yes	Yes	2.025 mm
Sokkia	Random bidirectional Digital width relation	Yes	No	16 mm
Topcon	Analog width variation	No	No	10 mm
Zeiss	Biphase	Yes	No	20 mm

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Image processing in DL

In-Homogenous Light Distribution

CCD Images
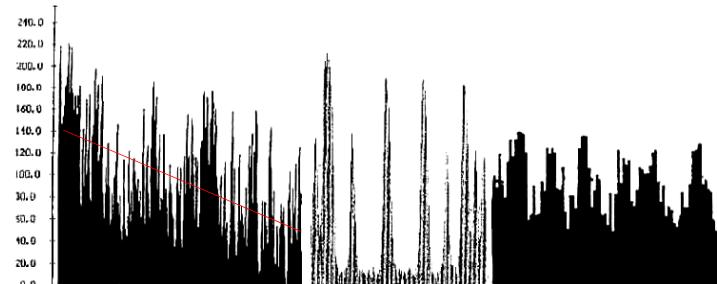
shaded staff   good SNR   bad SNR

Pixle's intensity correction by folding with trapezoidal function
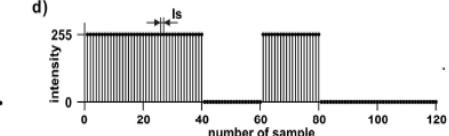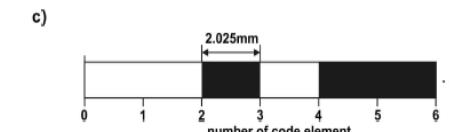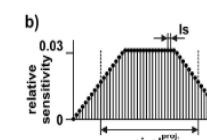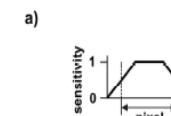
Leica: (a) Trapezoidal detector function, (b) sampling of the projected detector with Is, (c) image of the first 6 code elements on the staff and (d) their samples.

Woschitz 2003

Analogies of Human and Technical Image Processing

Lateral Inhibition
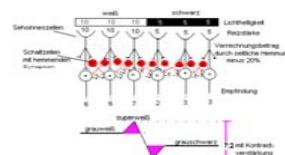
Radiometric Correction

Edge Operators

Canny

Sobel

....

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Ancillary Devices: Invarstaffs

Expansion coefficient: 0,6-1,2 ppm (Invar) ,Superinvar 0 ppm

Support (L&T)
Illumination

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Invarstaff Geometry

Invar Band

Body
(Aluminium)

Position of Invar Band
10mm
Center of Baseplate

geomETH
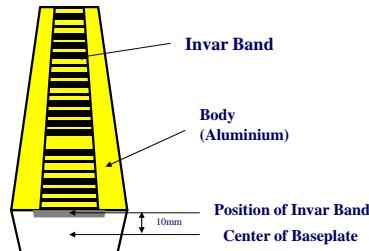
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Centering Rings from NEDO

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Staff Support (L&T)

New Staff Illumination by Riesen& Stettler

Stettler&Riesen

Stettler&Riesen
Solothurn

Aktuelle Digitalnivellierhersteller

➢ **Leica**

➢ **Trimble (Zeiss)**

➢ **Sokkia Topcon**

➢ **First Optical Industry Factory (FOIV)**

Leica Family NA 2000/3000 DNA03/10

The new Leica Digital Level Family

The WILD Leica Development NA 2000/3000
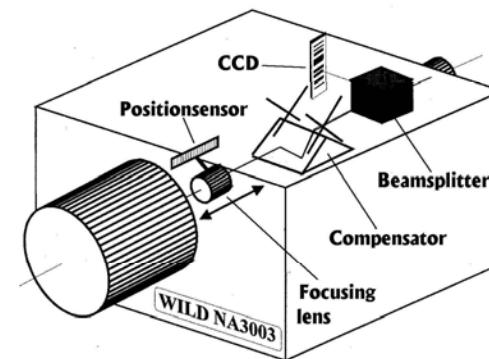
Section of the NA2000

Inside the NA2000

Design – Inside Leica Level

➢ **Magnetic dampened compensator**
➢ **The use of incandescent or halogen lighting is also possible.**
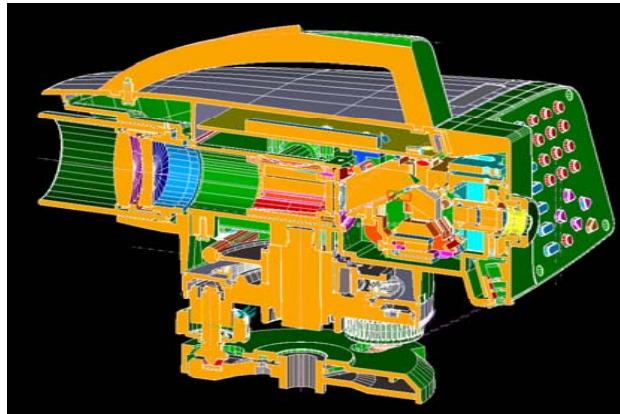
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The Leica Code
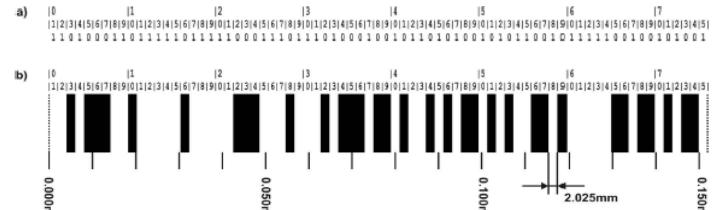
Figure 2.5: Leica's code pattern: (a) the code sequence and (b) the representation of 75 code elements at the lower end of the staff (0.000m – 0.152m).

Thesis Woschitz

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The Correlation Procedure of Leica
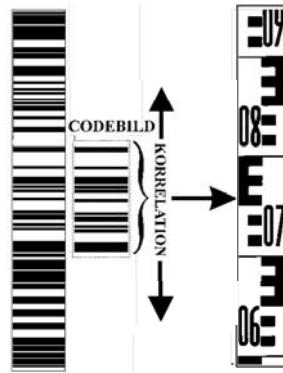
Geodätische Messtechnik - Prof. Dr. H. Ingensand ETH Zürich

The Scale Problem
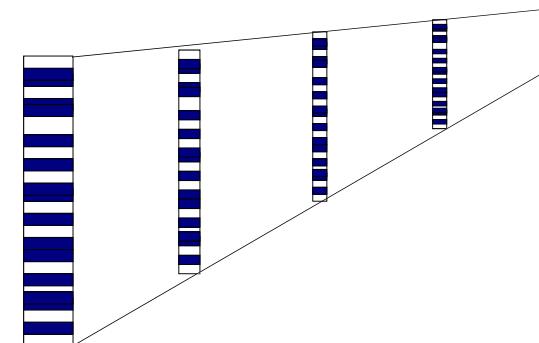
*Geodätische Messtechnik - Prof. Dr. H. Ingensand* ETH Zürich

The Correlation „Mountain" of the Leica DL
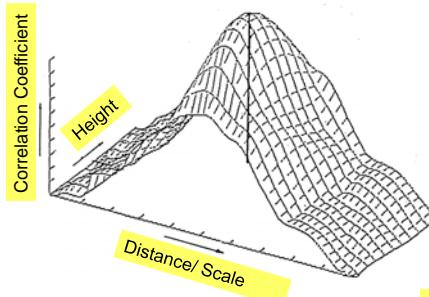
Two dimensional correlation

$$\rho_{QP}(D,H) = \frac{1}{n}\sum_{1}^{256} Q_i \bullet P_i(D,H)$$

$Q = signal$

$P(D,H) = reference\ signal$

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The Determination of the Best Correlation

About 50 000 correlation in the whole range

4.050 m

One bit correlation

Height

0.000 m

0.00 m   Distance   100.00 m

Focus Position

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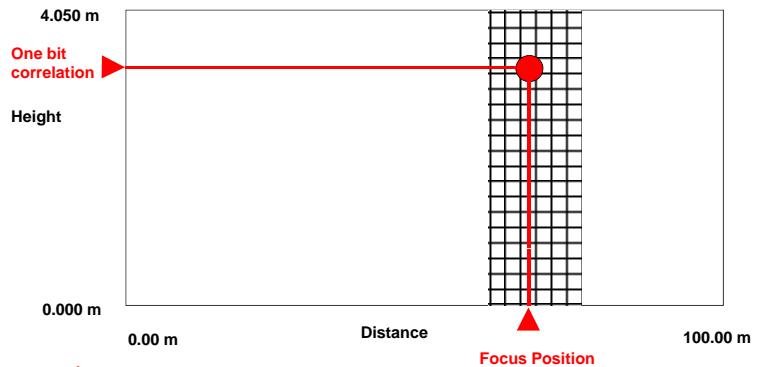
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The One Bit Coarse Correlation

$$\rho_{QP}(d,h) = \frac{1}{n}\sum_{1}^{n-1} Q_i(y) \otimes P_i(d,h)$$

$Q \qquad = signal$

$P(d,h) = reference\ signal$

$\otimes \qquad = EXNOR\ operator$

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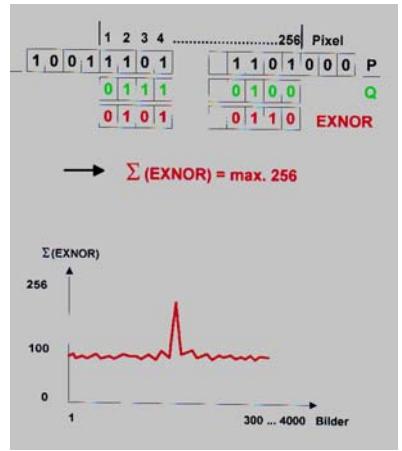
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Normalized 8-bit correlation

$$\rho_{QP}(D,H) = \frac{\dfrac{1}{n}\sum_{1}^{n-1} Q_i \bullet P_i - \overline{Q} \bullet \overline{P}}{\sqrt{\dfrac{1}{n}\sum_{1}^{n-1} Q_i^{\,2} - \overline{Q}^{\,2}} \bullet \sqrt{\dfrac{1}{n}\sum_{1}^{n-1} P_i^{\,2} - \overline{P}^{\,2}}}$$

$Q \qquad = signal$

$P(d,h) = reference\ signal$

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Technical Data DNA03/10

➢ **Standard deviation per km double levelling**
  ➢ *With invar staff: 0.3mm / 0.9mm*

➢ **Field of View**
  ➢ *Coarse correlation – 2° at 50m*
  ➢ *Fine correlation – 1.1°*

➢ **Range**
  ➢ *Staff: 0 – 4.05m*
  ➢ *Distance: 1.8m – 110m*

➢ **Standard deviation of distance measurement**
  ➢ *5mm/10m (500ppm)*

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DiNi 10, DiNi 20
Digital Levels

Perfect Measurement
The Easy Way
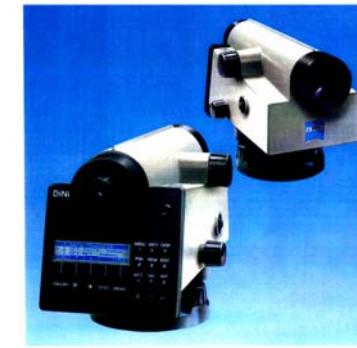
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Zeiss/Trimble DiNi

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Inside the Zeiss DiNi
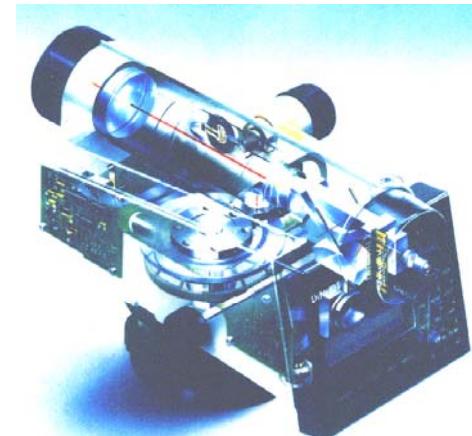
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Optical Layout of the Zeiss/Trimble
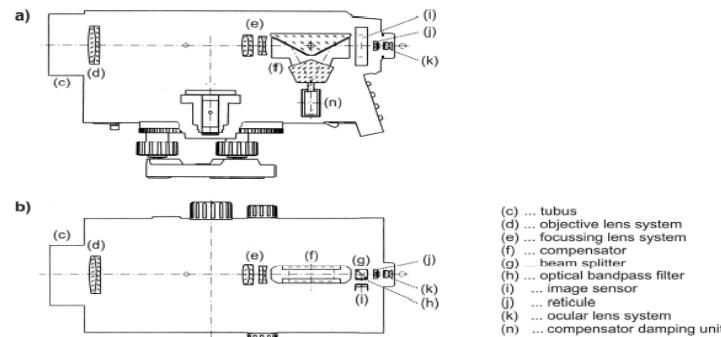
Figure 2.8: (a) Vertical and (b) horizontal cross section of the Zeiss DiNi10 (Feist et al., 1995).

(c) … tubus
(d) … objective lens system
(e) … focussing lens system
(f) … compensator
(g) … beam splitter
(h) … optical bandpass filter
(i) … image sensor
(j) … reticule
(k) … ocular lens system
(n) … compensator damping unit

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The Zeiss Code

Coarse code

Near field code

a 30 cm section of the rod gives a 1 byte information
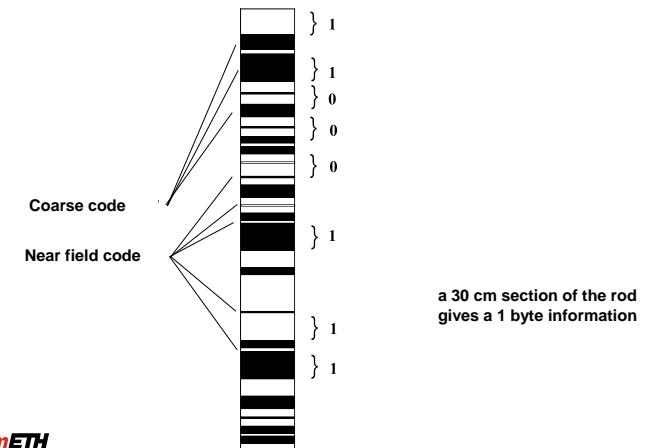
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The Zeiss Biphase Code

Zeiss DINI codepattern and corresponding digital values

codepattern

digital value
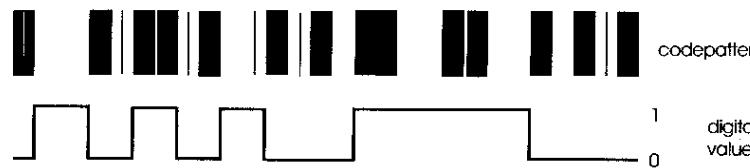
Geodätische Messtechnik - Prof. Dr. H. Ingensand   ETH Zürich
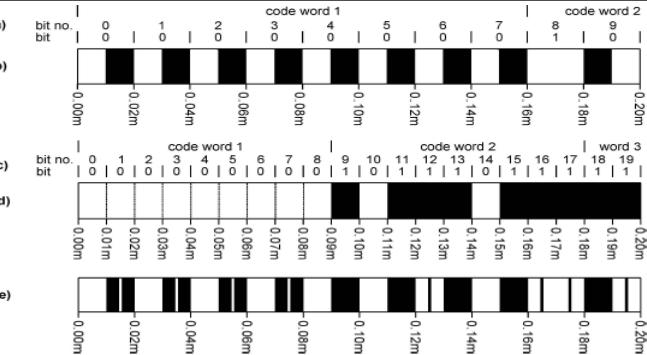
Zeiss Code

Figure 2.9: Trimble/Zeiss's code pattern shown for the lower end of the staff (0.000m – 0.200m, after Gürtler, 1995 and Schlosser, 1995): The standard code as a (a) pseudo-stochastic code sequence and as a (b) bi-phase code. The near-field-code as a (c) pseudo-stochastic code sequence and its (d) image. (e) Combination of standard and near-field-code.

Thesis Woschitz

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Sampling of the Code

Woschitz/2003
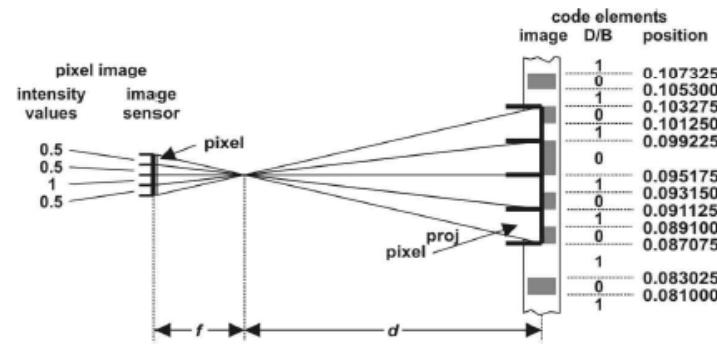
Geometric Method (Zeiss)

DIGITISING

STAFF   IMAGE
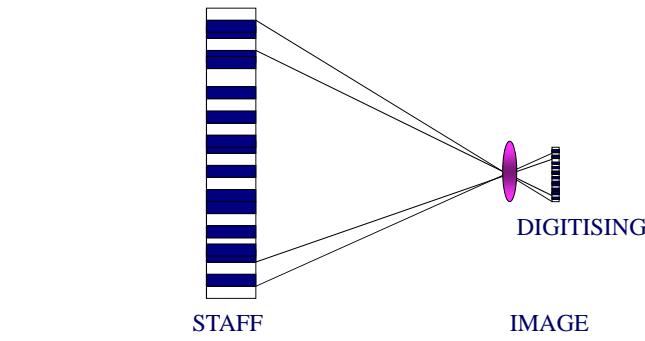
Determination of the Scale of the Image (Zeiss)
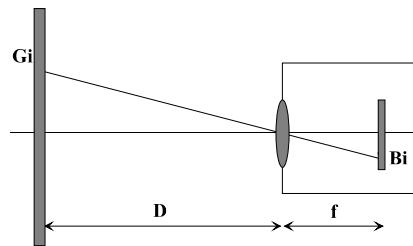
$$\frac{D}{f} = \frac{G_i}{B_i} \Rightarrow D \cdot B_i = f \cdot G_i$$

Using a +/-15 cm Interval:

$$A = \frac{N \cdot g}{B_{+15} - B_{-15}} \Rightarrow \text{Distance}$$

According the Reichenbach method with stadia lines

The Zeiss Calculation Procedure

G_{i+n}

g_i

G_i

$$H = \frac{1}{N} \sum_{i=0}^{N-1} [g \cdot (C_i + 1/2) - A \cdot \frac{B_{i+1} + B_i}{2}]$$

Middle of the code bar

Number of Codeword (Lower edge)

Position of a single interval

Position of the optical axis in the image (CCD)
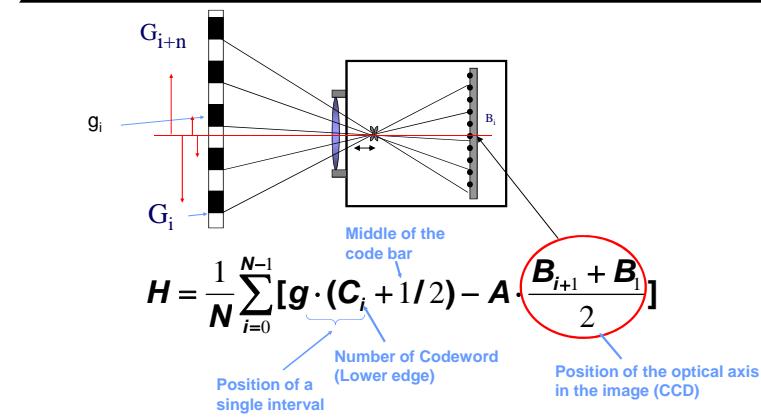
Problems with the Zeiss/Trimble Instruments

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Two Epoch Height-Differences versus Height
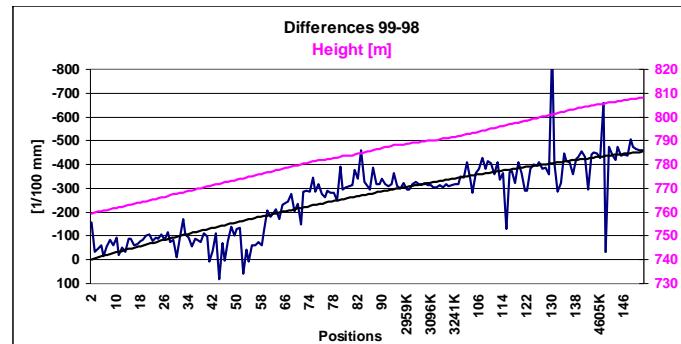
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Experimental Setup (ETHZ 2000)

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Intensity Distribution

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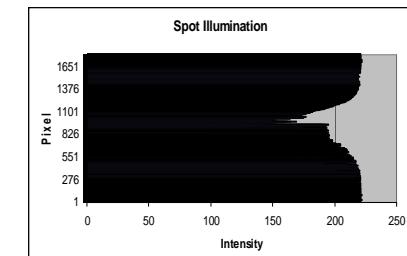
Inhomogeneous Illumination at Back- and Foresight Shot

Spot   Spot
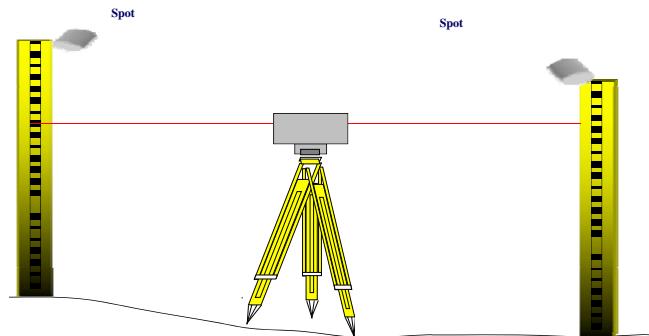
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The levelling staff-end problem superimposed with inhomogenious illumination

Deviations as a function of the position and illumination: Landestopographie top down
Software version.: 1.05

[m]
2.00
1.90
1.80
1.70
1.60

-0.20   0.00 [mm] 0.20   0.40

Deviations as a function of the position and illumination: Landestopographie down-top
Software version.: 1.05

[m]
2.00
1.90
1.80
1.70
1.60

-0.01   0.04 [mm] 0.09   0.14

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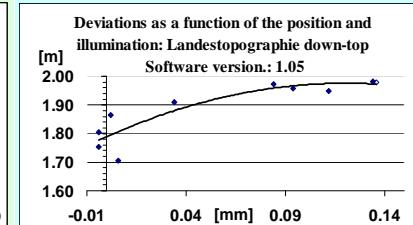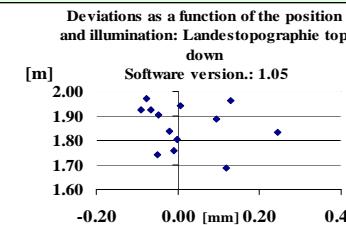
Temperature Function of Zeiss DiNi (UNI Karlsruhe)
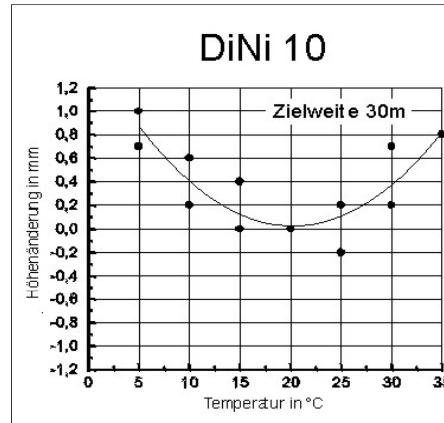
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The Topcon Precision Digital Levels
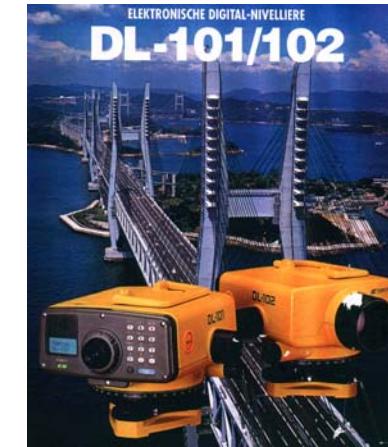
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The Topcon Digital Level

The Topcon DL103 (Construction Level)

DL-103 Specifications

Telescope: 26x30mm 1°30'4   0.9m Erect Image

Compensator: 10'   0.5"

HeigtAccuracy (Standard Deviation for 1km double run leveling) 1.8mm w/Fiberglass Staff 2.0mm w/Aluminum Staff 2.5mm0.1mm/1mm (0.001ft/0.01ft) selectable

Distance Measurement: 1cm(0.02ft)

Accuracy (D= measuring distance: m) (0.1% x Dm) (D>10m), 10mm (D≤10m)±(0.15% x Dm) (D>10m), 15mm (D≤10m)2m to 60m (7ft to 197ft)2 sec.10'/2mm

Others: 128 x 32 dot, Dot matrix LCD with backlight (55.01mm x 16.29mm)

RS-232C5

Rod height/difference of elevation

Built-in timer for auto power–off360° or 400gonAA battery x 420 hours (Alkaline)-20°C to +50°C (-4°F to +122°F)IPX 6196(H) x 158(W) x 232(L) mm
7.7(H) x 6.2(W) x 9.1(L) inch2.3kg

 StaffLength: 3m[9.84ft] Length: 5m [16.40ft] Length: 5m [16.40ft]

The Topcon Code
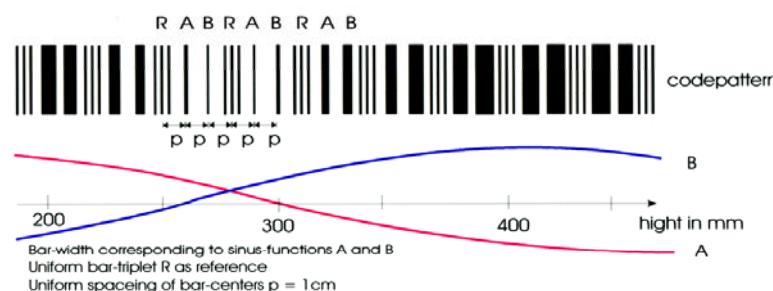
R A B R A B R A B

codepattern

p p p p p

B

200   300   400   hight in mm

A

Bar-width corresponding to sinus-functions A and B
Uniform bar-triplet R as reference
Uniform spaceing of bar-centers p = 1cm

The SOKKIA SDL30/SDL50

The Sokkia Code
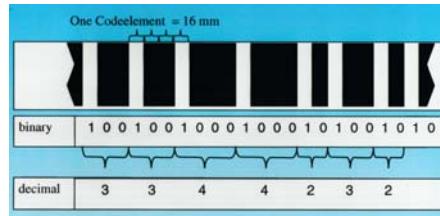
Close Range

5 Value Resolution

Long Range

3 Value Resolution

Properties of the Bar Code of SDL30

Relations between pattern width, code and distance.

Pattern width (mm)	0-5 code (Short dist.)	0-2 code (Long dist.)	Image size at 100m	Image size at 10m
3	0	0	1.05µm/ 1 cell	84µm/ 10.5 cell
4	1	0	1.40µm/ 1 cell	112µm/ 14.0 cell
7	2	1	2.45µm/ 3 cell	196µm/ 24.5 cell
8	3	1	2.80µm/ 3 cell	224µm/ 28.0 cell
11	4	2	3.85µm/ 4 cell	308µm/ 38.5 cell
12	5	2	4.20µm/ 4 cell	336µm/ 42.0 cell

Sokkia Topcon SDL1X Digital Level

Autofokus

0,2 mm Precision ?

Daten SDL1X

First Optical Instrument Factory (FOIF); China

FOIF

FOIF EL 100

Das EL100 ist entworfen, um optimale Entscheidung für Ihre überblickenjobs durchzuführen. mit diesem neuen digitalen Niveau kann alle ebnenarbeit automatisch, schnell und ökonomischer ausgeführt werden. Das Drücken einer Taste kann Ihre Arbeit schneller und produktiver bilden. Einfach visieren Sie den Personal an, fokussieren Sie und betätigen Sie den Knopf, die Resultate erscheinen. Er ist so einfach

Die Höhengenauigkeit ist ±1.5mm, und optischer Messwert und Elektronikmesswert sind selben.
 Genießen Sie mühelose Datenübertragung.
 Die Benutzer, die zu andere, FOIF Niveaus laufen zu lassen gewohnt sind, passen leicht sich dem EL100 an.

 Die messende Abstandsstrecke ist bis 110m.

FOIF Code

Overview of the Performaces of DL

Hersteller	TOPCON	LEICA	SOKKIA	TOPCON SOKKIA	Trimble	FOIF
Instrument	DL102	DAN03	SDL30	SDL 1X	DiNi10/11/12	EL100
Accuracy mm/Km Double levelling		0.4 mm Invarstaff	1,5 mm	0,2mm	0,3 mm	1,5 mm
Distance (Resolution)	1 cm	1 cm	0.1% x D	1 cm	1cm	ka
Compensator Type Accuracy Range	Pendulum 0.3" ± 15'	Pendulum 0.3" ± 15'	Pendulum - > ± 15'	Pendulum - > ± 15'	Pendulum 0.2" ± 15'	ka
Measurement time	4 s	4 s	> 3 s	> 3 s	4 s	ka
Range	2-60 m Invarstaff	1.5 - 60 m Invarstaff	1.6 – 100 m Standard-staff	1.6 – 100 m Invarstaff	1.5- 100 m Invarstaff	110 m
Required Field of View	no information	2°	1°20'	1°20'	Minimum 30 cm	ka

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End

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