Apparatus of straightness measurement with tensioned wires.

1999. 1. 25

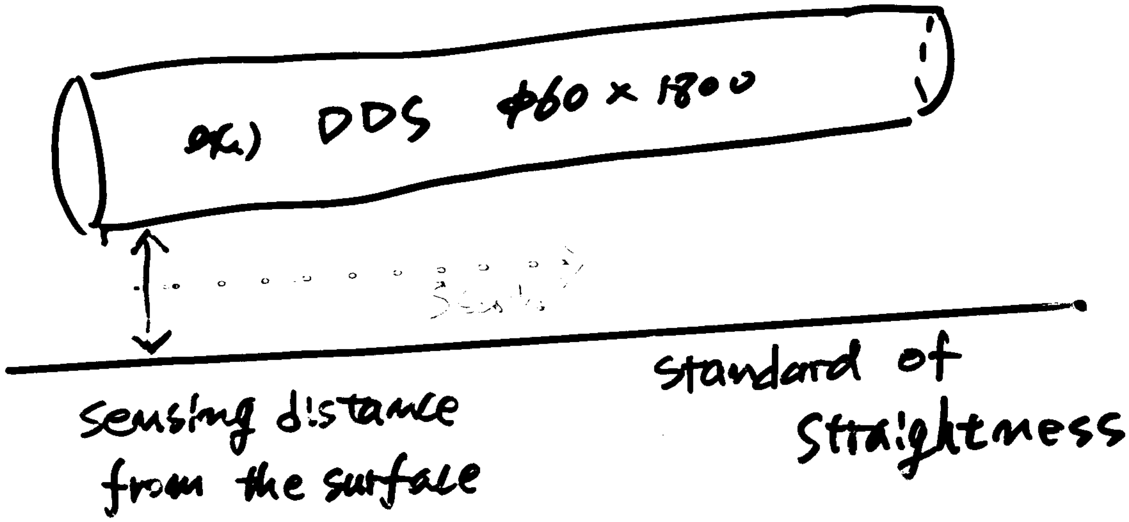
KEK

T. Suzuki

[1] Current apparatus

[2] Some ongoing tests

Methods of straightness measurement



	Sensing	Standard
(1)	Microsense	Linear guide + Laser Interferometer
(2)	LaserScan Micrometer	Tensiond wires
(3)	multi-Microsense (x2 or x3)	database

(1) : for DDS , stacked disks on v-block
$0 \leq \theta \leq 90°$

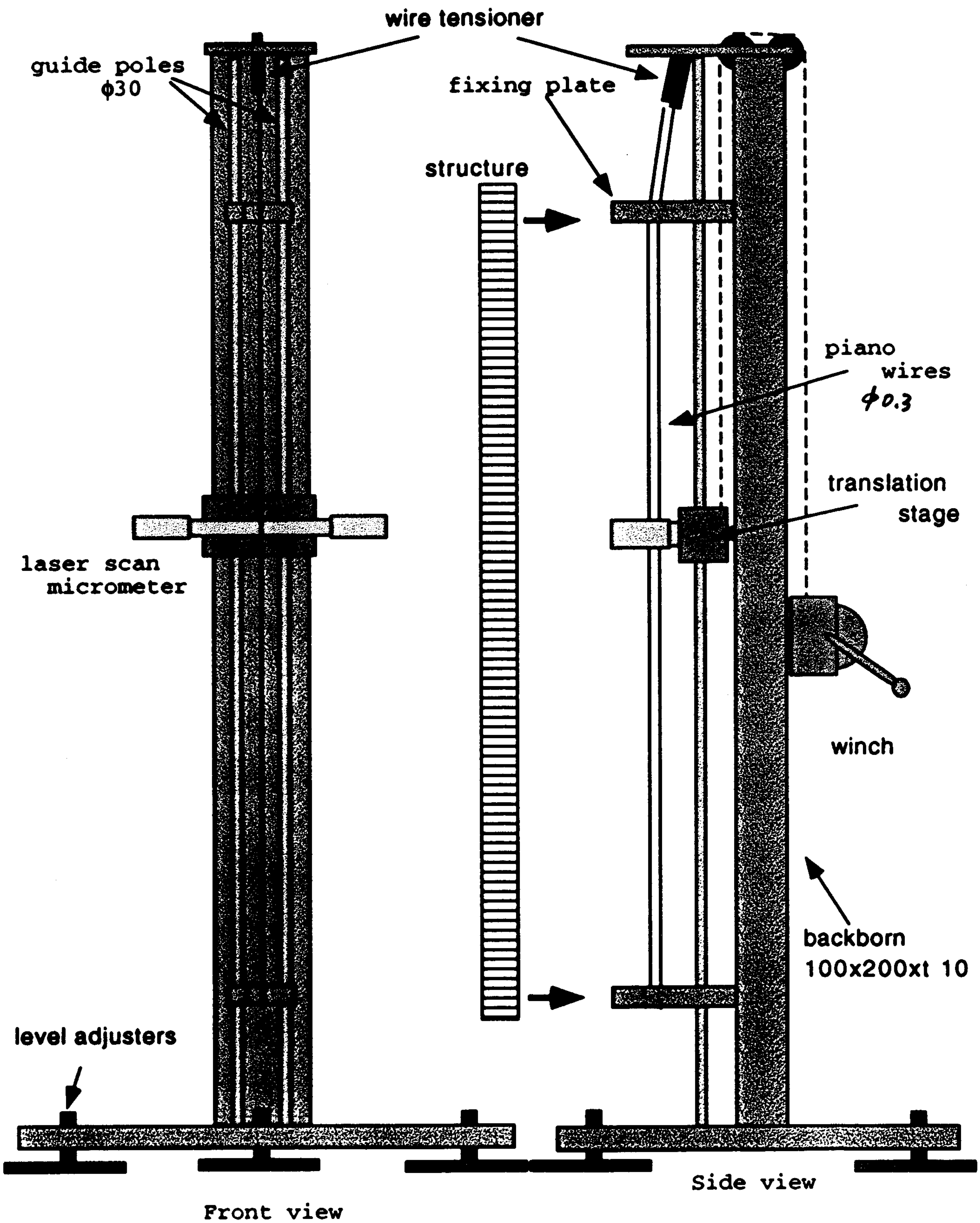
(2) : 〃 , prebonded , d-bonded
$\theta = 90°$

(3) : under development for LC applications
Basic experiments have already done.

(Kiyomo)

Schematic drawing of a straightness measurement

Projection of the structure is compered with a tensioned wire.



o Wires

$\phi 0.3$ piano wire

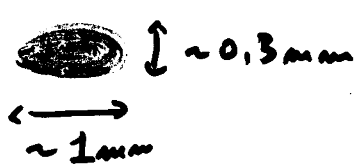
tension ~ 7 kgf

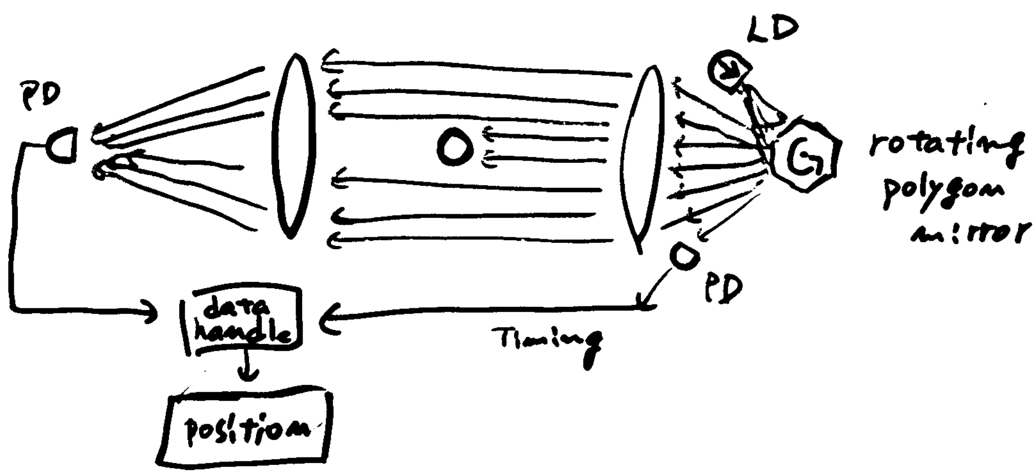
measured by the string vibration

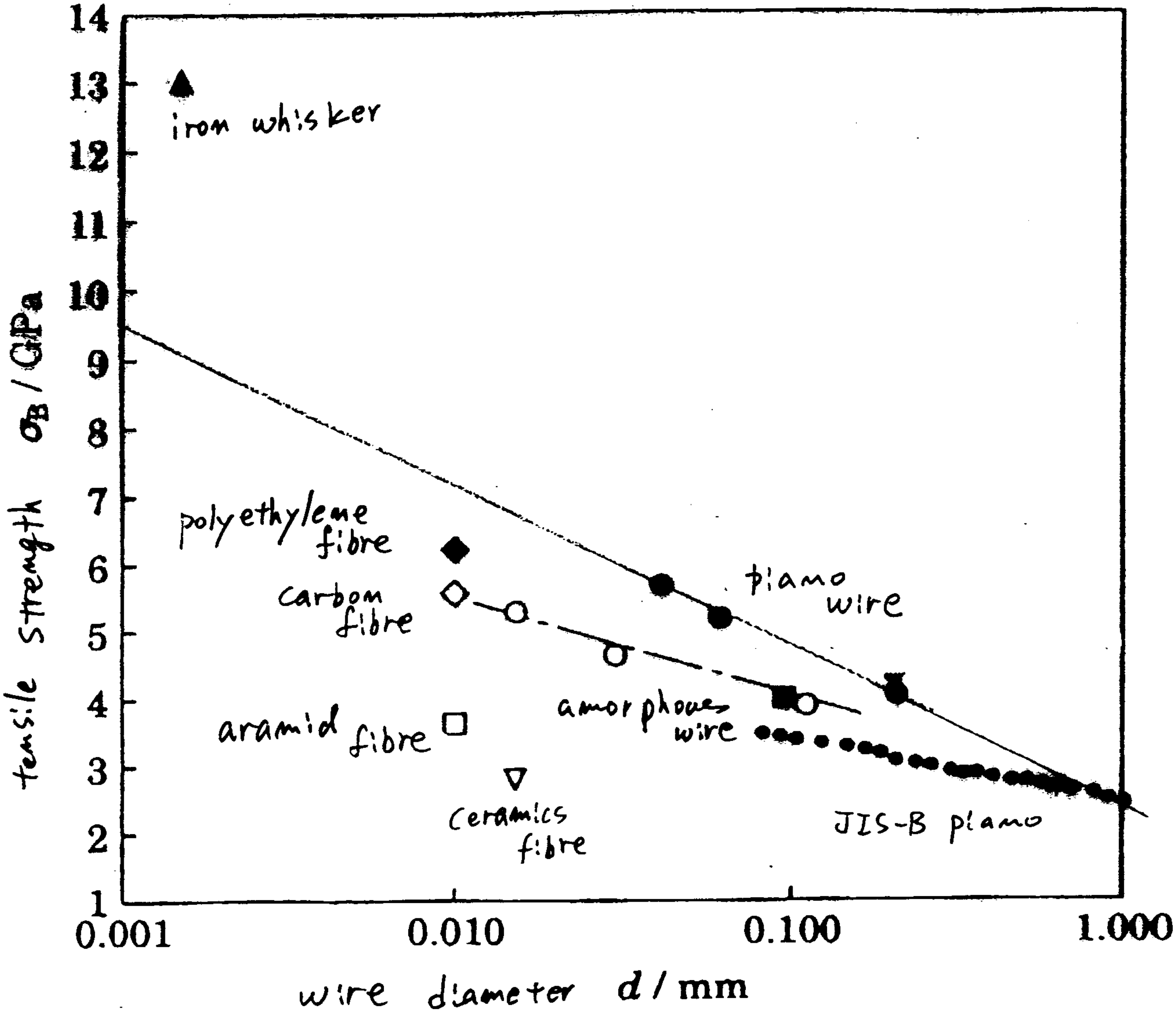
o Laser Scan Micrometer

Specifications

Scan range	40 mm
min. detectable size	0.2 mm
sensing span	160 ± 40 mm
accuracy	± 2 μm
Laser	670nm 0.8mW LD







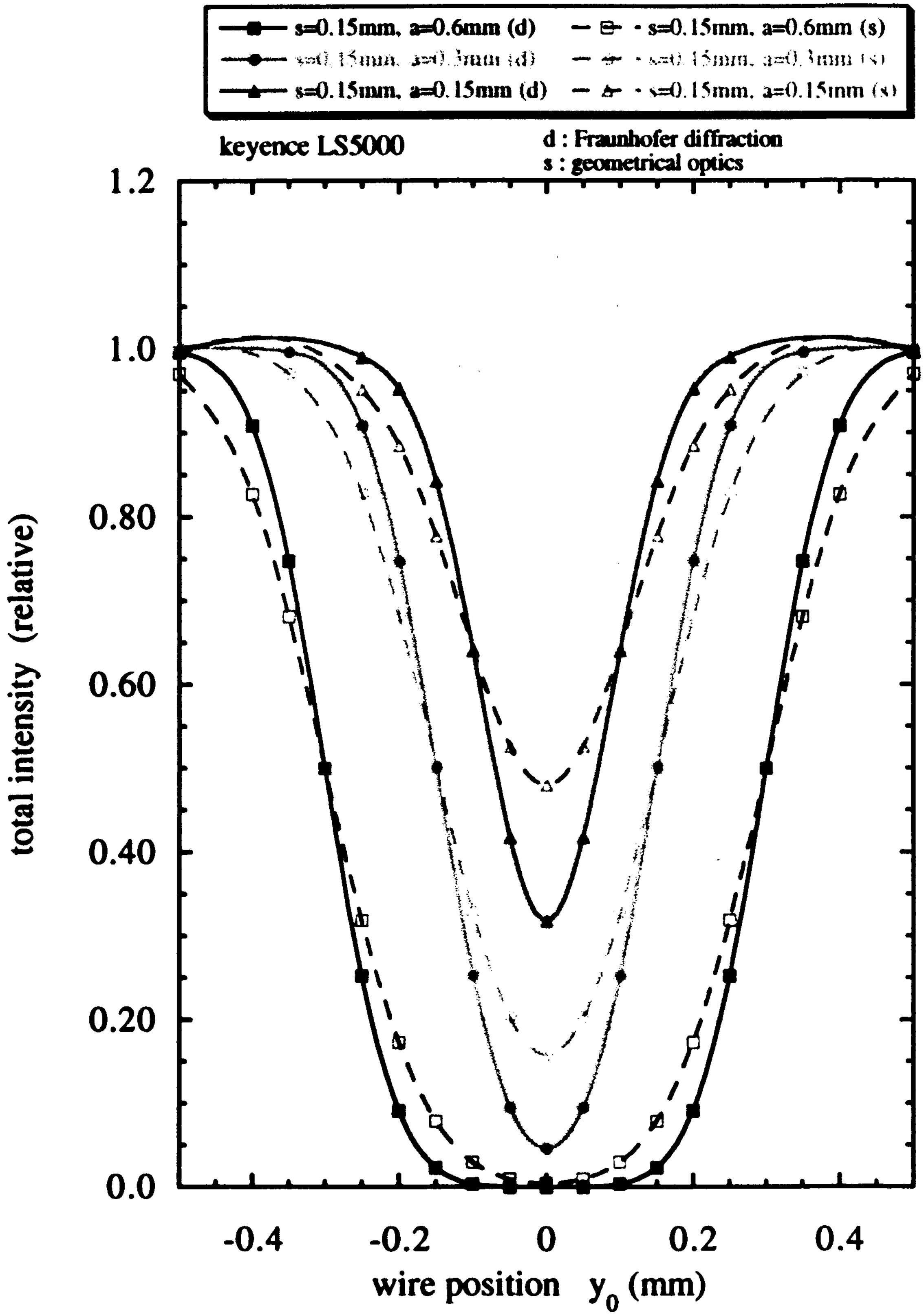
Strength of some engineering materials

Intensity of laser beam on PD

9 Dec. 97

laser beam profile : exp(- y^2 / s^2)
wire position : y_0
wire diameter : a

laser wavelength : 1μm
focal length of the lens : 100mm
(calc. : wire_keyence2.nb)



MacintoshHD:HyperHD:jlc:xtube:ihi:wire_keyence_diff1.d

TS-6

[2] ongoing test of the apparatus

(i) confirm the performance of current apparatus

(ii) improve for RDDS construction

(2-1) wire tensioner and cramp

applicable tension $\lesssim 9.5$ kgf (slip)

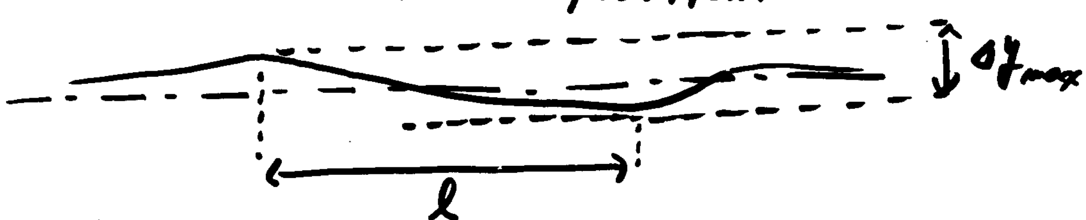
stability $\frac{\delta F}{F} \simeq -1.0 \sim -1.4\% / 5.3$ hours

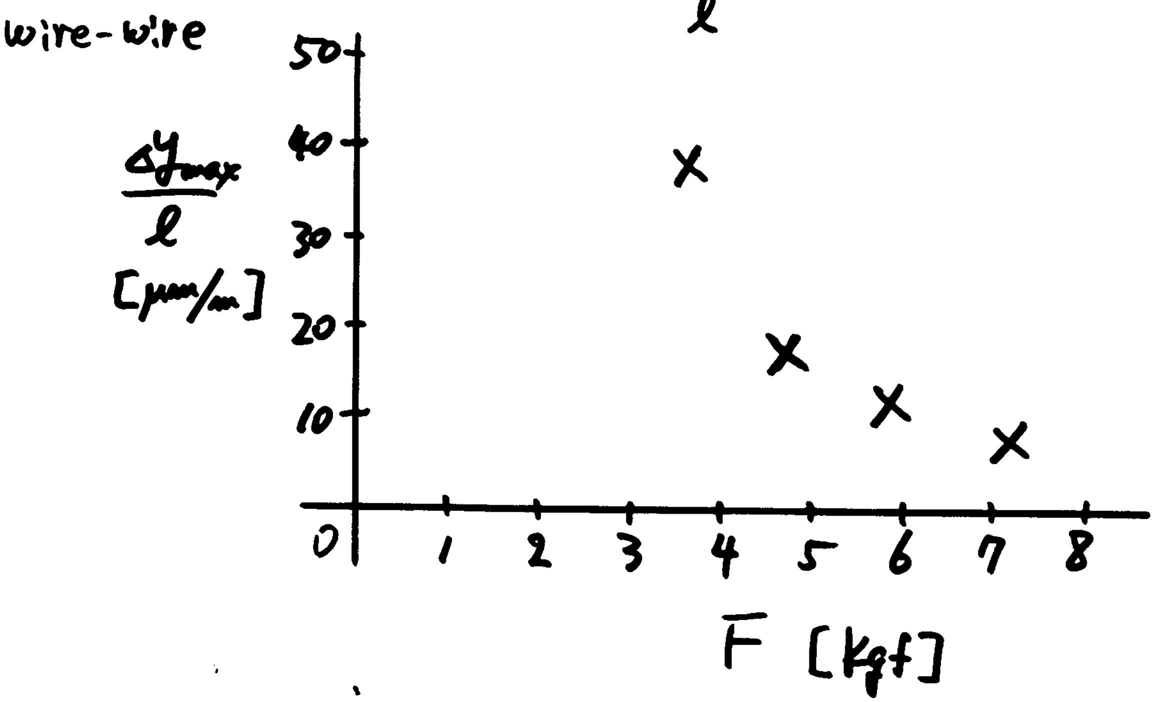
in $F = 7.3$ kgf

($\sigma = 1$ GPa)

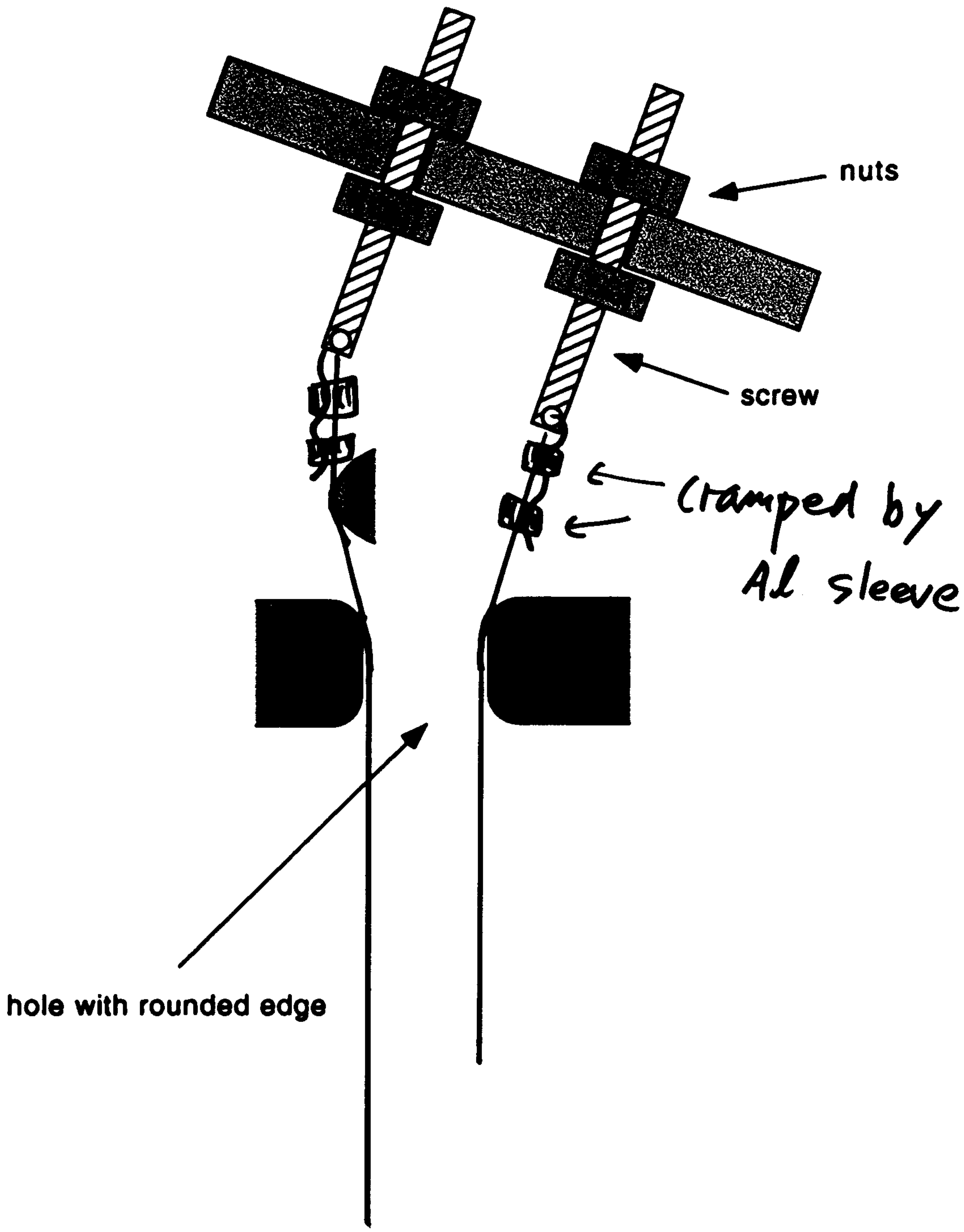
increase friction of cramp → larger tension

(2-2) tension vs lateral deflection



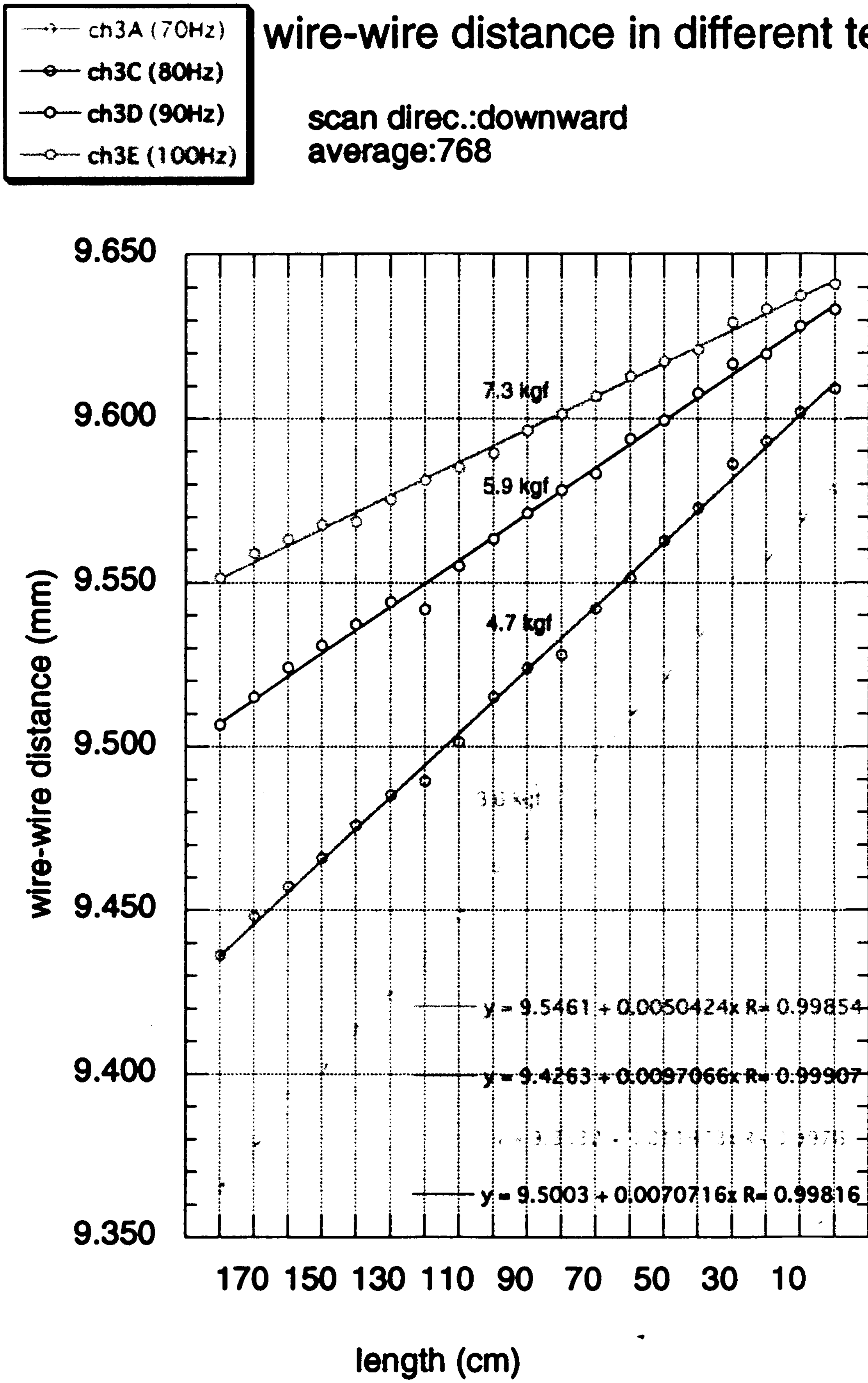


Wire tensioner and cramp



wire-wire distance in different tension

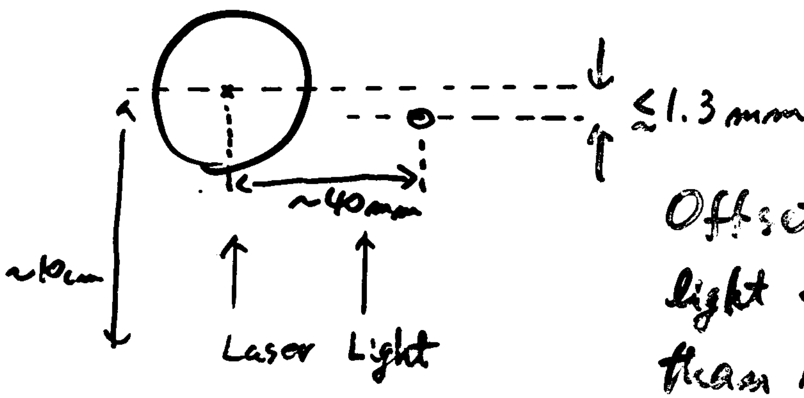
scan direc.:downward
average:768



wi0119_ch3.kgd

(2-3) Effect of torsional motion of Stage

structure - wire (center-center) ~ 40mm



Offset along the laser light should be smaller than 1.3mm.

(1mm deform → < 5μm read out)

(2-4) averaging

simple moving average

read out $\{y(t_i)\}$

$$y_{av}(t_n) = \frac{1}{N}\sum_{j}^{N} y(t_{n-j})$$

random noise $\sigma_{av} = \frac{\sigma_y}{\sqrt{N}}$

(2-5) move/stop : transient response

Response looked faster than 10ms.

Delay effect was observed when averaging used.

Further test items

(F-1) Selection of better wire material.

(F-2) Wire deformation near edge.

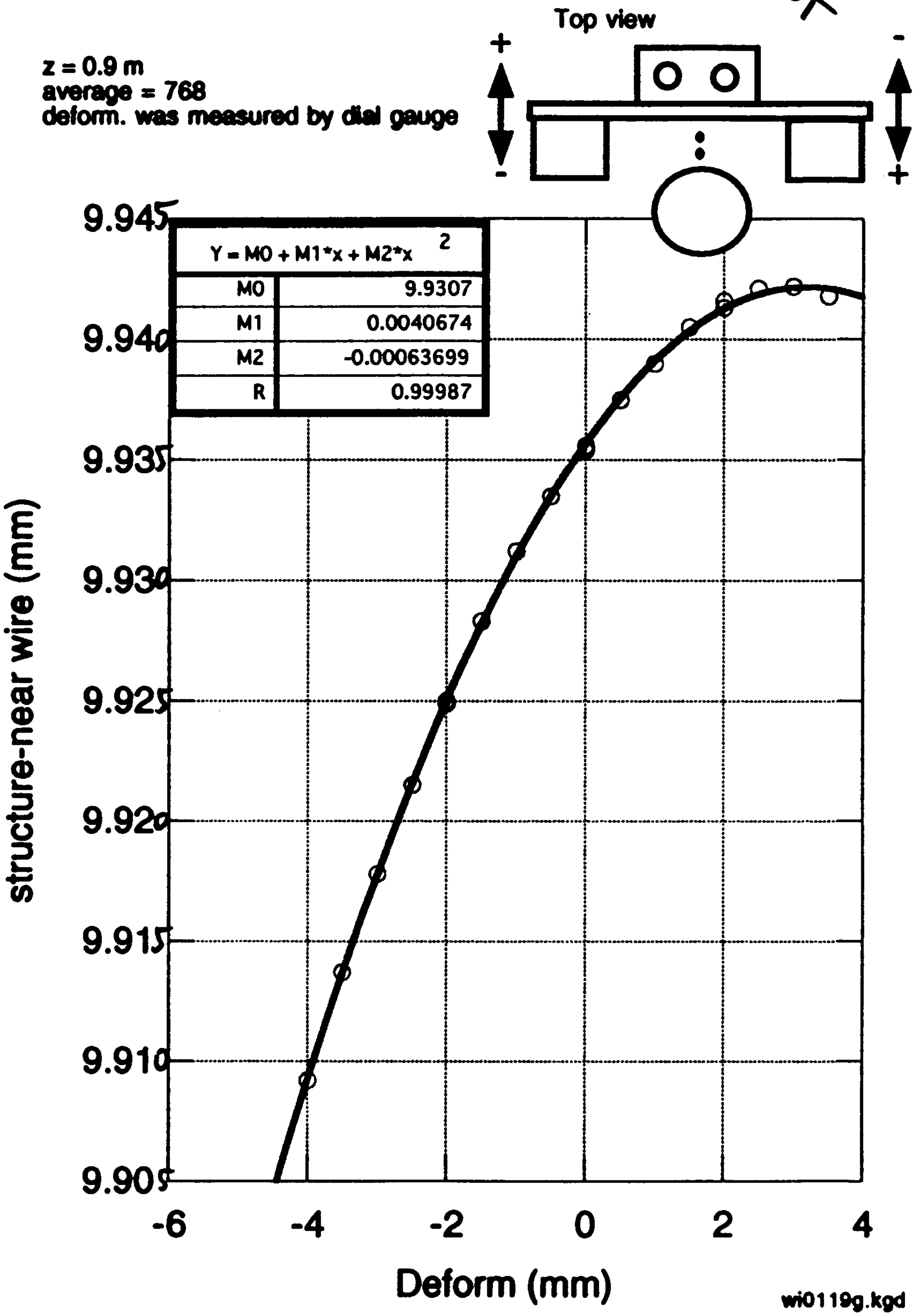
(F-3) Linearity in dynamic range of L.S.M.

micro

19 Jan. 1999

Effect of torsional movement of Laser Scanning Meter

z = 0.9 m
average = 768
deform. was measured by dial gauge



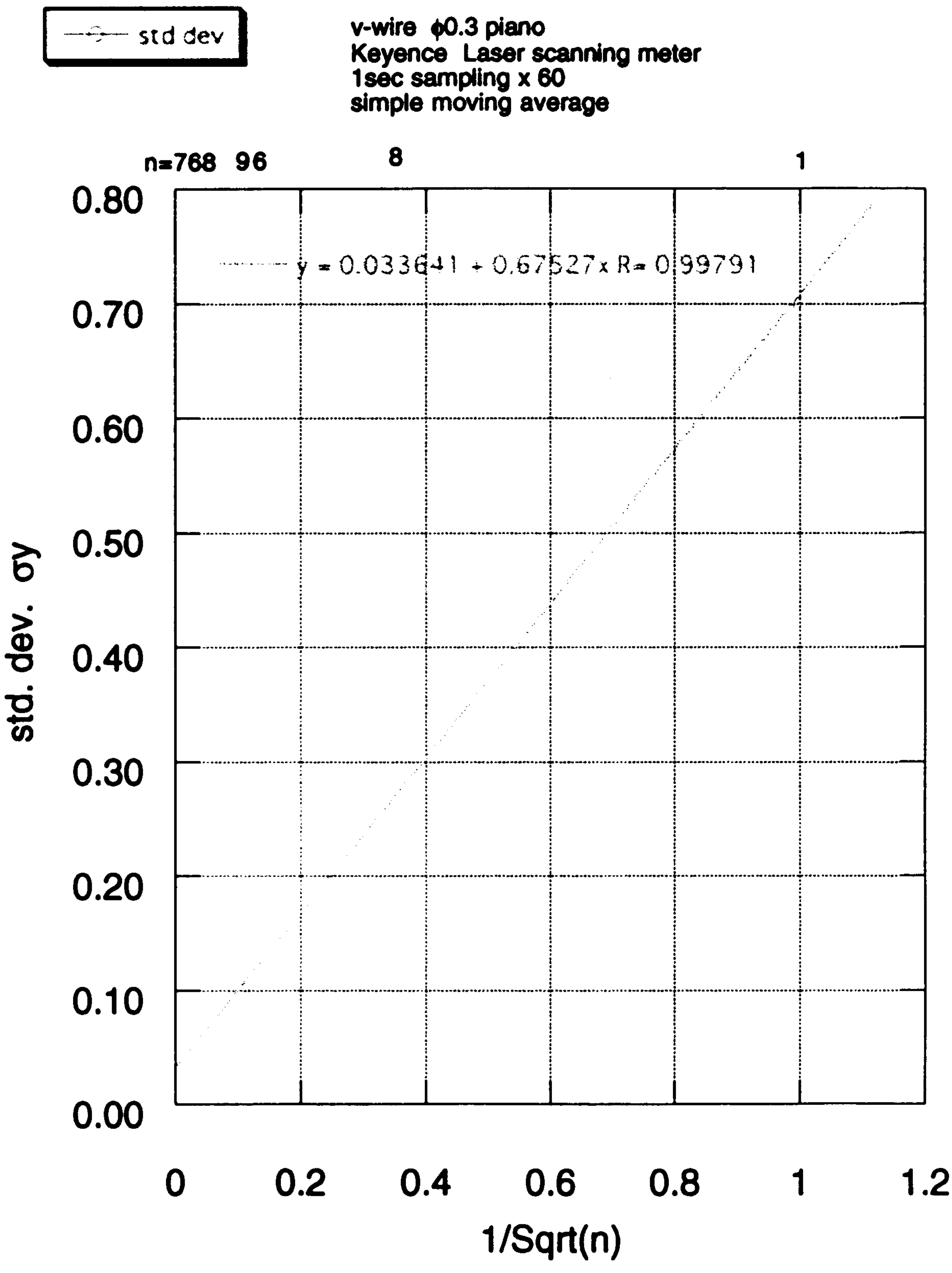
$Y = M0 + M1*x + M2*x^2$	
M0	9.9307
M1	0.0040674
M2	-0.00063699
R	0.99987

wi0119g.kgd

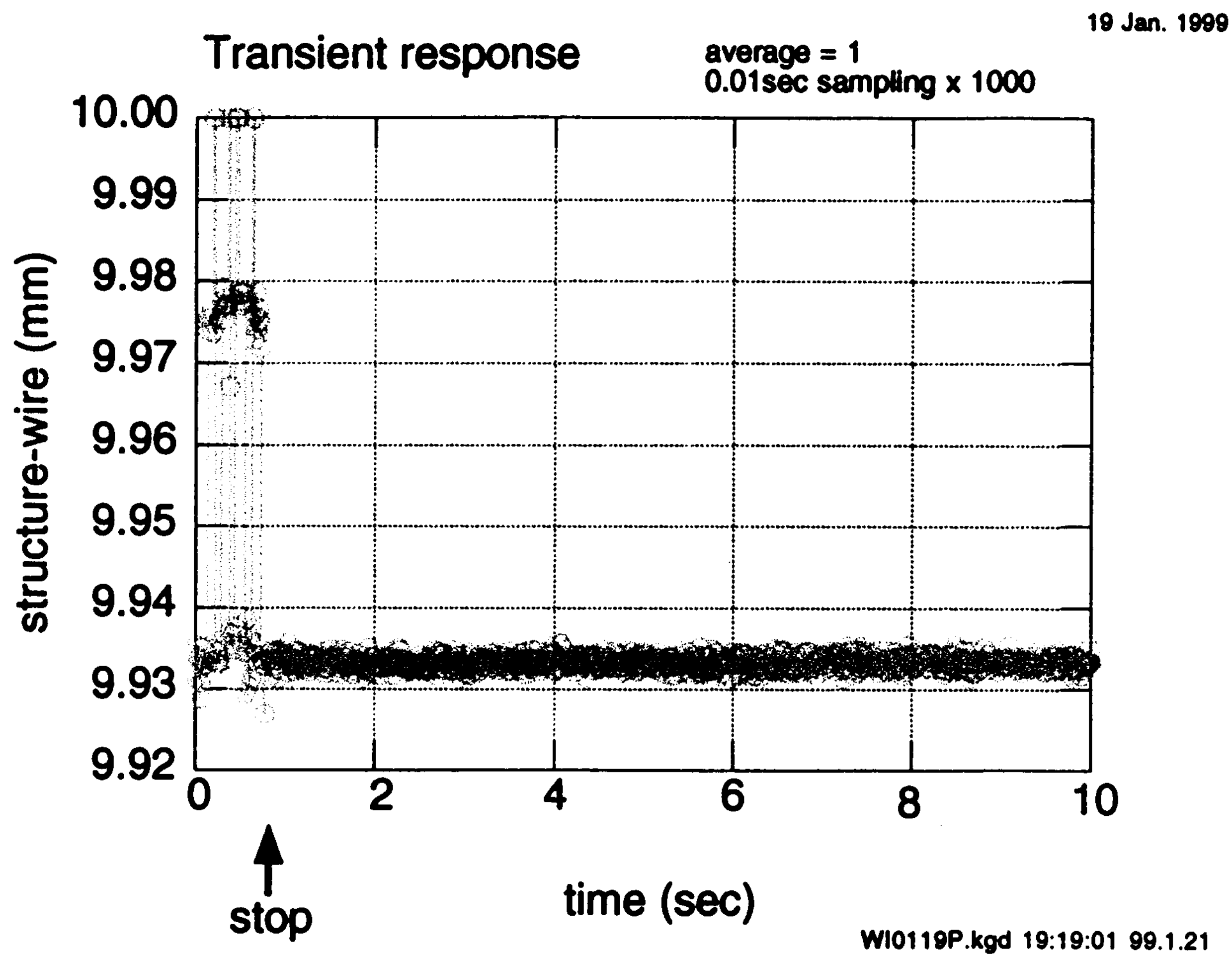
TS-11

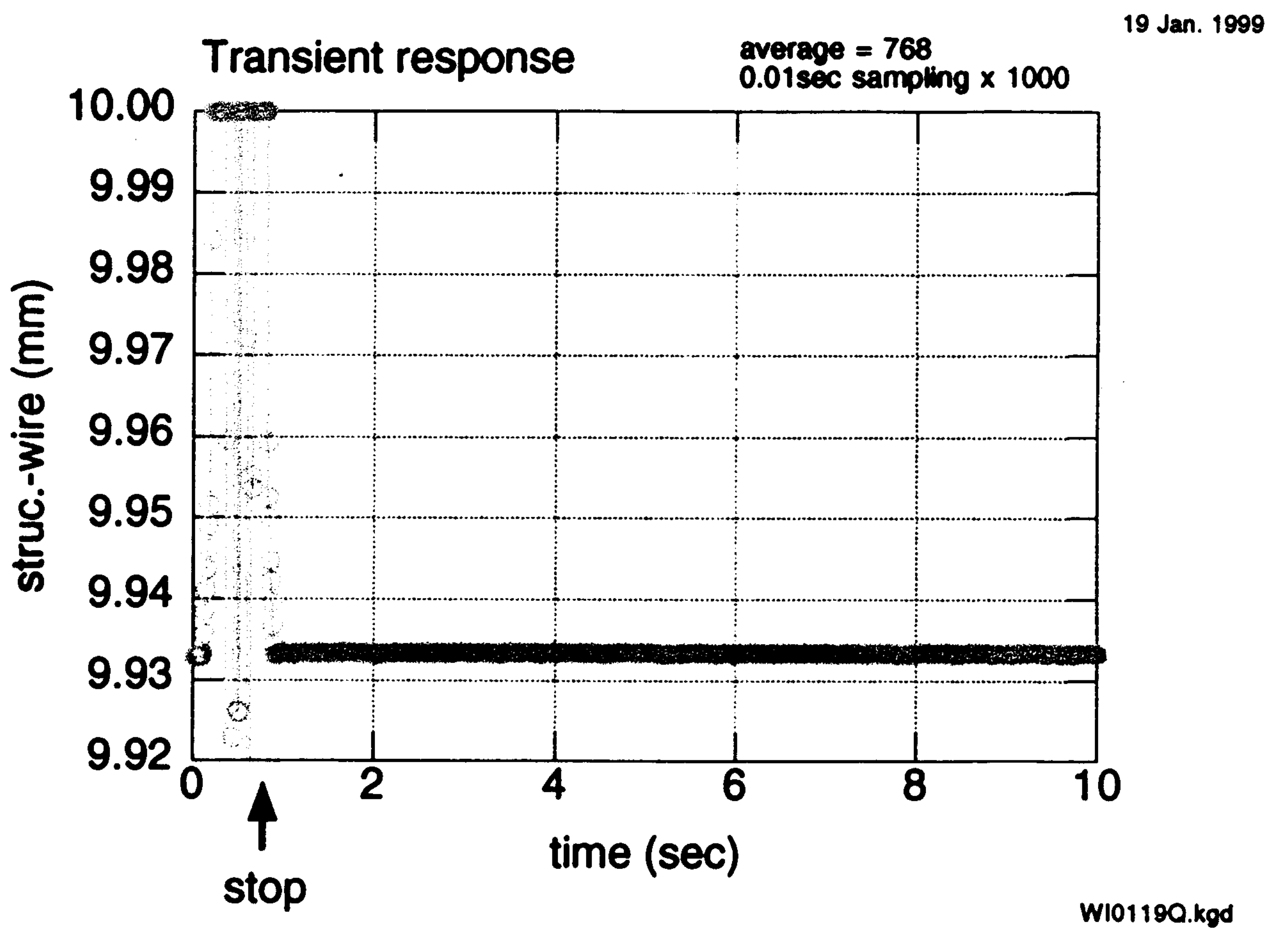
19 Jan. 1999

Resolution.vs.Averaging.plot



TS-12

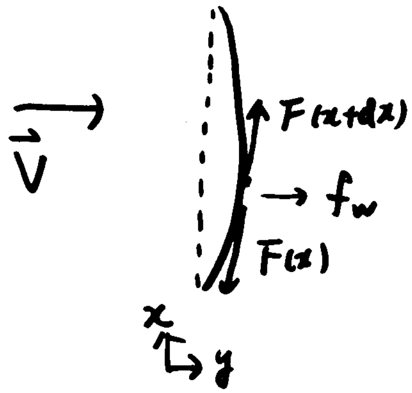

19 Jan. 1999
Transient response
average = 1
0.01sec sampling x 1000
10.00
9.99
9.98
9.97
9.96
9.95
9.94
9.93
9.92
structure-wire (mm)
0
2
4
6
8
10
stop
time (sec)
WI0119P.kgd 19:19:01 99.1.21


19 Jan. 1999
Transient response
average = 768
0.01sec sampling x 1000
10.00
9.99
9.98
9.97
9.96
9.95
9.94
9.93
9.92
struc.-wire (mm)
0
2
4
6
8
10
stop
time (sec)
WI0119Q.kgd

TS-13

(F-4) Vibration of floor, acoustic noise.

(F-5) wind



l : length

F : tension

f_w : drag force of wind.

$$\left|\frac{dy}{dx}\right| \ll 1 \Rightarrow F\frac{d^2y}{dx^2} = \frac{f_w}{l}$$

$$\therefore\ y(x) = \frac{f_w}{2Fl}\left(x-\frac{l}{2}\right)\left(x+\frac{l}{2}\right)$$

max. deflection

$$|y|_{max} = \frac{f_w l}{8F}$$

$$(\text{Drag force}) = \frac{1}{2}\rho V^2 A C_D$$

C_D : drag coefficient

ρ : density of fluid

V : fluid velocity

A : projected area of the wire

$l = 2m$, $d = 0.3mm \Rightarrow A = 6.0 \times 10^{-4} m^2$

$F = 7.3\ kgf = 72\ N$

Drag Coefficient of cylinder C_D

$R_e < 0.5$ $\quad C_D = \dfrac{8\pi}{Re \cdot (2.002 - \log Re)}$ (Lamb)

$5 \lesssim Re \lesssim 40$ $\quad C_D = \left(0.707 + 3.42 \dfrac{1}{\sqrt{Re}}\right)^2$ (Imai)

⋮

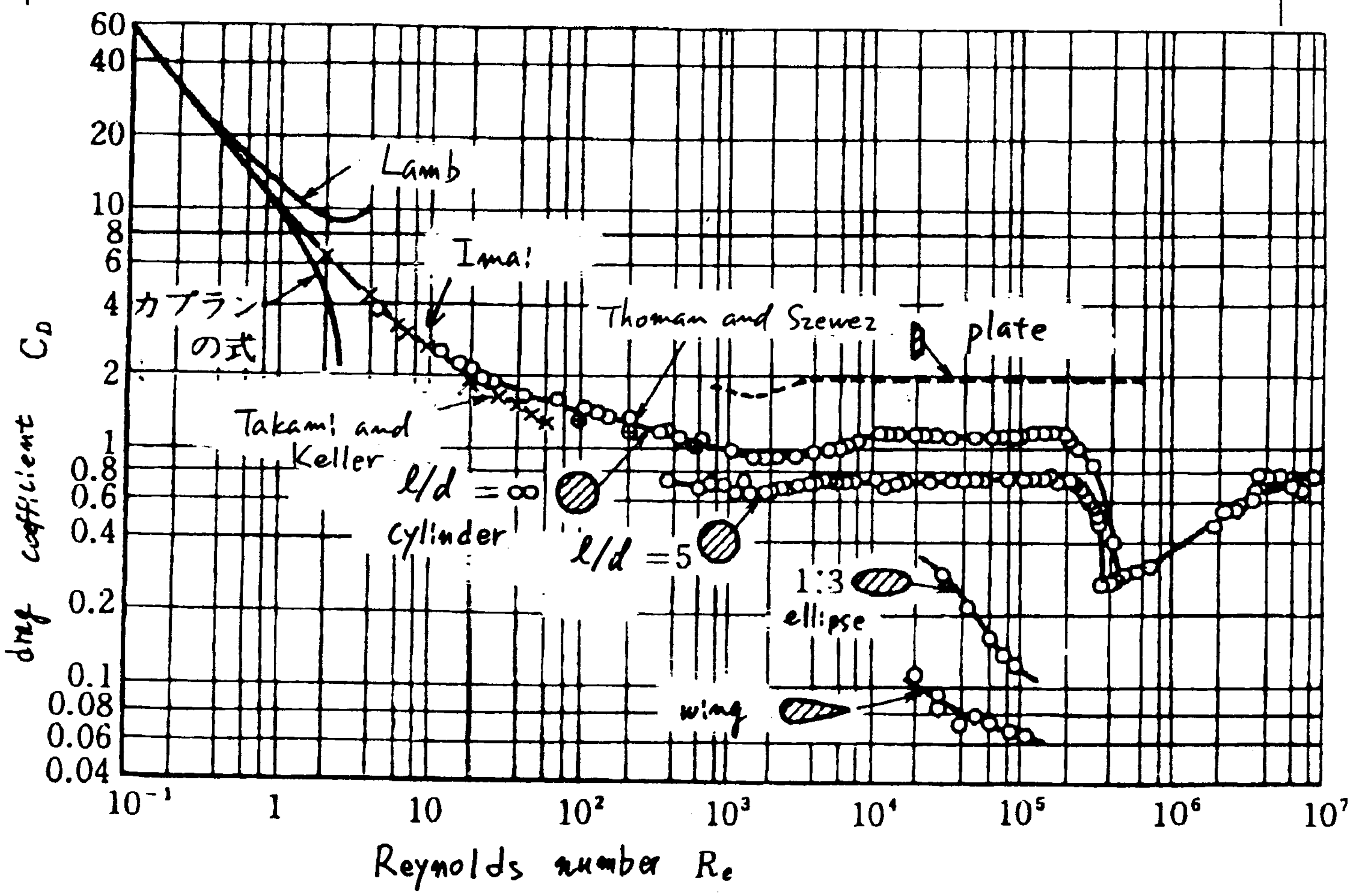
$2 \times 10^4 \lesssim Re \lesssim 2 \times 10^5$ $\quad C_D = 1.2$: Constant

ex.) wire $\phi 0.3$ mm, $l = 2$ m

air 1 atm 25°C dry $\quad \rho = 1.184$ [kg/m³]

$\mu = 1.820 \times 10^{-5}$ [Pa·s]

$$Re = \frac{\rho V d}{\mu} = 19.5 \times \left(\frac{V}{1\,m/s}\right) \times \left(\frac{d}{0.3\,mm}\right)$$



$$\therefore f_w = \frac{1}{2}\rho V^2 A C_D = \frac{1}{2} \times 1.181 \times 1^2 \times 6.0 \times 10^{-4} \times 2$$

$$= 7.1 \times 10^{-4}\ N$$

(air, $V = 1\ m/s$
$\phi 0.3\ mm$, $l = 2\ m$)

$$\therefore |y|_{max} = \frac{f_w l}{8F}$$

$$= \frac{7.1 \times 10^{-4} \times 2}{8 \times 72} = 3 \times 10^{-6}\ m$$ //

Vibration induced by kalmann voltex ?