NIRS instrument basics and a new multiple NIRS system with the CDMA technique

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Near Infrared Spectroscopy (NIRS) calculates hemoglobin parameters, such as changes in oxyHb and deoxyHb.

http://209.73.52.252/assets/pdf/hpspdf/C8686.pdf

Natural posture example.

http://www.nict.go.jp

Brain activation can be measured in the natural posture.

There have been many NIRS systems in Japan.

http://www.hitachi-medical.co.jp/opt-e/index.html

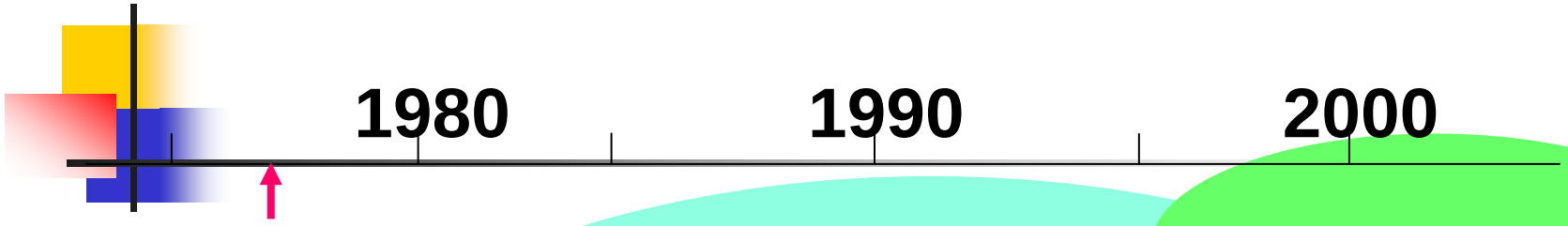
http://www.hpk.co.jp/eng/products/SYSE/Niro300E.htm

http://www.med.shimadzu.co.jp/products/om/index.html(in Japanese)

These pictures were several years ago.

The companies released the new products.

NIRS **History** ***in Japan***



1977
Jobsis（Duke Univ.）
Science 198:1264

International Patents
(Unpatented in Japan)

Spectroscopy

Hamamatsu

Shimadzu

Omron

Topography
Hitachi

Tomography

NEDO Project
（1992 - 1999）
Tamura, Yamada (AIST)
Shimadzu, Hamamatsu

Hitachi

Arridge (UCL)

Delpy (UCL)
Chance (U. Penn.)
Tamura (Hokkaido Univ.)

United States Patent [19]
Jöbsis

[11] 4,281,645
[45] Aug. 4, 1981

[54] METHOD AND APPARATUS FOR MONITORING METABOLISM IN BODY ORGANS

[75] Inventor: Frans F. Jöbsis, Durham, N.C.

[73] Assignee: Duke University, Inc., Durham, N.C.

[21] Appl. No.: [illegible]

[22] Filed: Jun. 28, 1977

[51] Int. Cl.³ A61B 5/00
[52] U.S. Cl. 128/633
[58] Field of Search ..... 128/2 R, 2 L, 2.05 F, 128/2.05 P, 2.05 V, 633, 634, 664, 665, 2.06 R; 356/43–45, 39, 432

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3,674,008	7/1972	Johnson	356/432
3,677,648	7/1972	Dorsch	356/40
3,811,777	5/1974	Chance	128/2 L
3,825,342	7/1974	Lubbers et al.	356/41
3,830,222	8/1974	Chance	356/39
3,998,550	12/1976	Konishi et al.	128/2 L
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Geddes et al., "Principles of Applied Biomedical Instrumentation", 1966, pp. 85–91.
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Lee et al., "IEEE Transactions on Biomedical Engineering", vol. 22, No. 3, May, 1975, pp. 248–249.

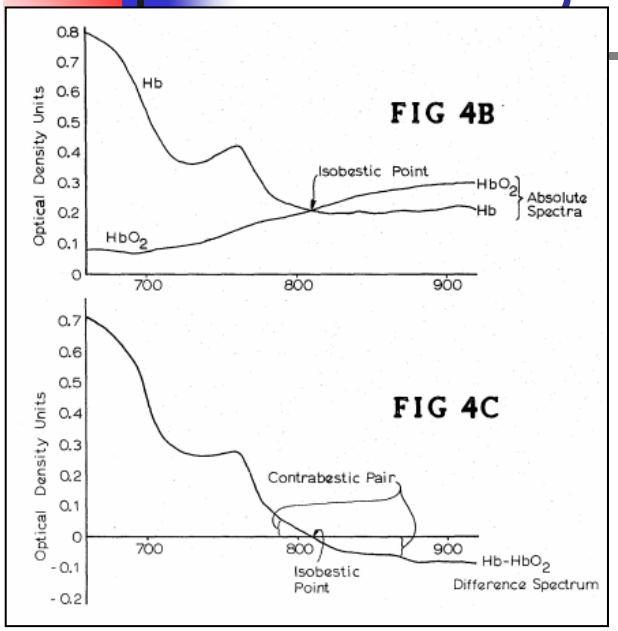
Primary Examiner—William E. Kamm
Attorney, Agent, or Firm—B. B. Olive

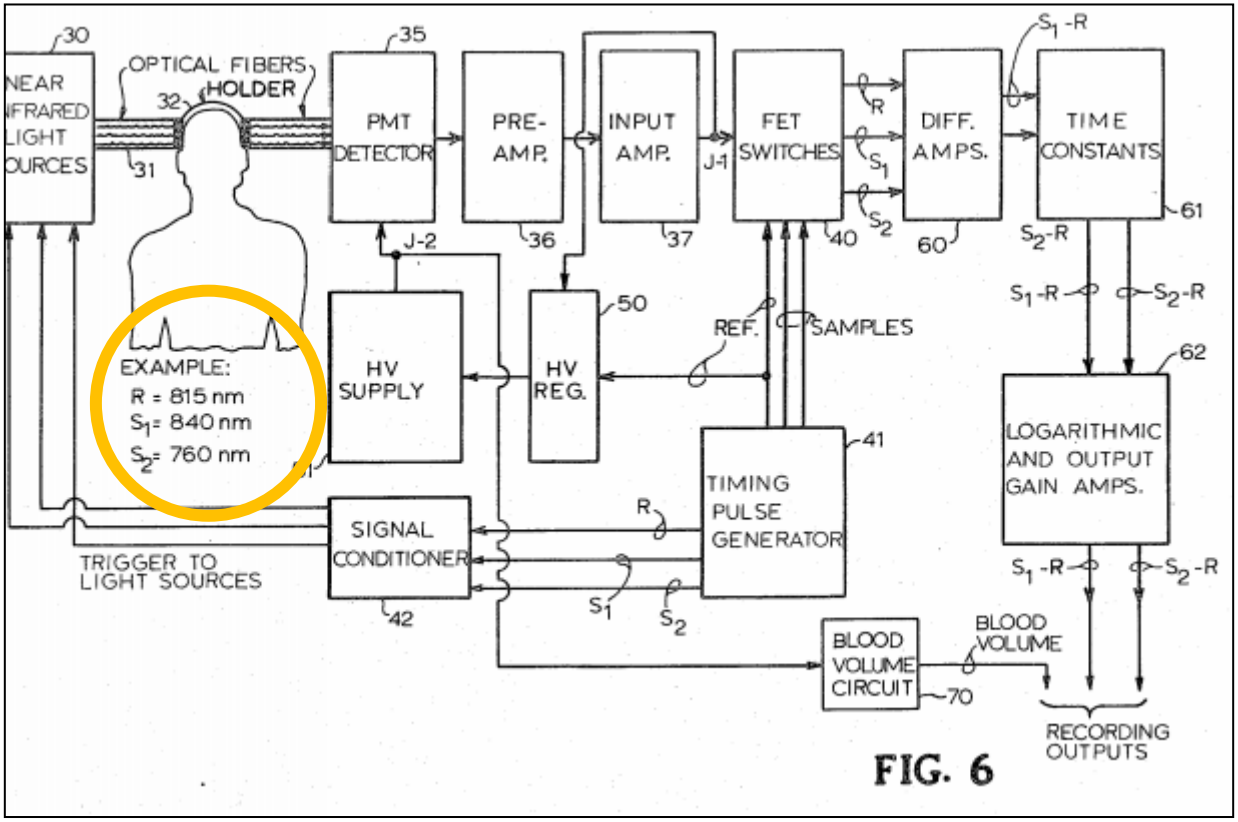
[57] ABSTRACT

A spectrophotometric transillumination method and apparatus are directed to non-invasive, continuous, atraumatic, in vivo, in situ monitoring of metabolism in a body organ. In the described applications, measuring and reference wavelengths within the near infrared region, i.e., 700–1300 nm, are utilized for non-invasive, continuous, atraumatic, in situ, in vivo monitoring of oxidative metabolism by monitoring oxygen sufficiency in an internal organ, e.g., the brain or heart, of a human or animal body. Advantage is taken of the critical characteristic of cellular enzyme cytochrome a, a3 within the optical path and within the radiated portion of the selected organ for absorbing the selected measuring wavelength and for light of this measuring wavelength, as well as at least one reference wavelength within the same defined infrared region and at a low, non-hazardous level of intensity to travel through and be detectable at the end of a relatively long path, e.g., of several centimeters length, which may include substantial content of bone as well as soft tissue. The selection of wavelengths, circuitry and method also provide techniques for compensating for changes in blood volume in the organ being monitored, for continuous monitoring of hemoglobin oxygenation and blood volume and for intermittent monitoring of blood flow rate.

67 Claims, 16 Drawing Figures

US patent 4281645, Jobsis, (Filed 1977)





US patent 4223680, Jobsis, (Filed 1977)

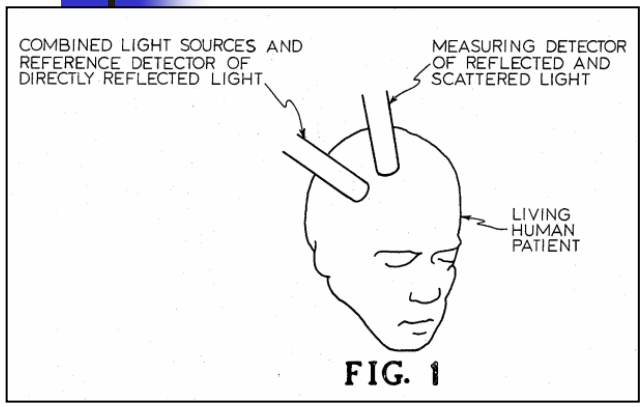


FIG. 1

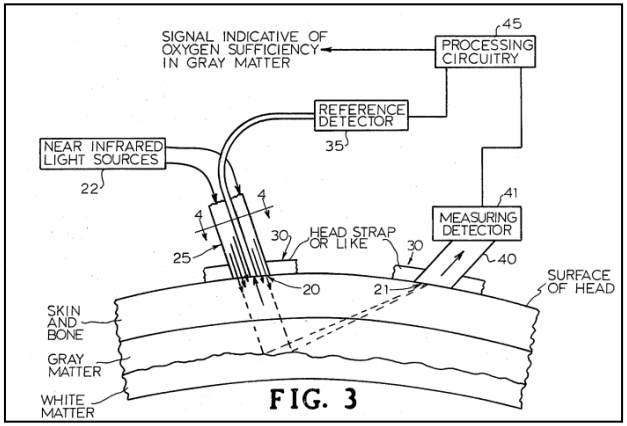


FIG. 3

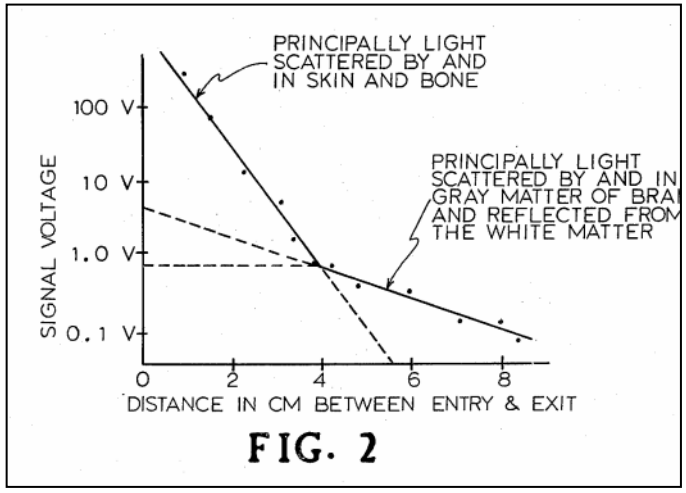


FIG. 2

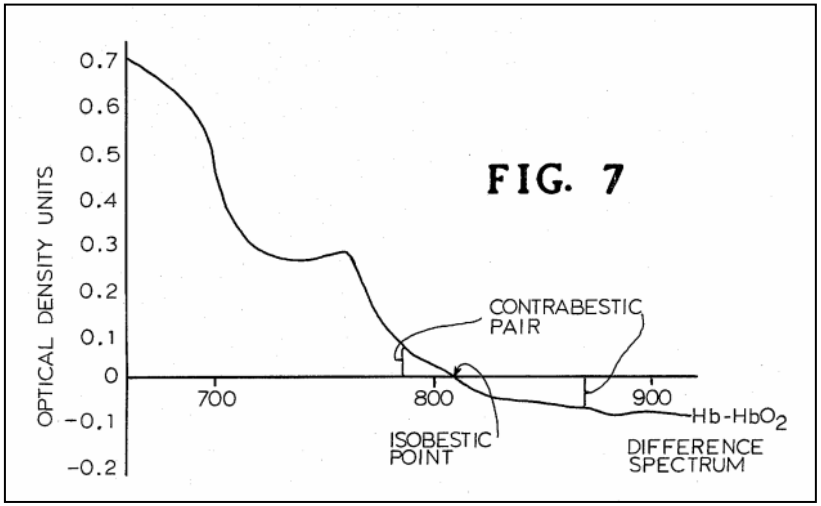
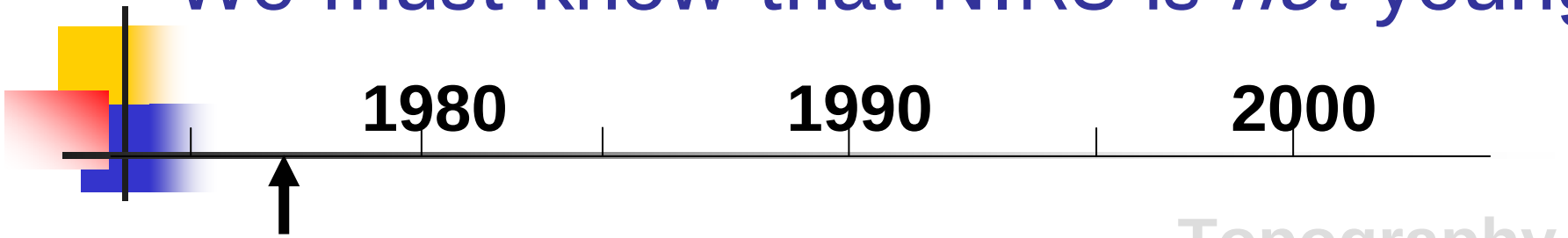


FIG. 7

We must know that NIRS is *not* young



Topography

Spectroscopy

NEED Breakthrough!

Tomography

Jobsis（Duke Univ.）
Science 198:1264

X ray CT
Hounsfield (1973)

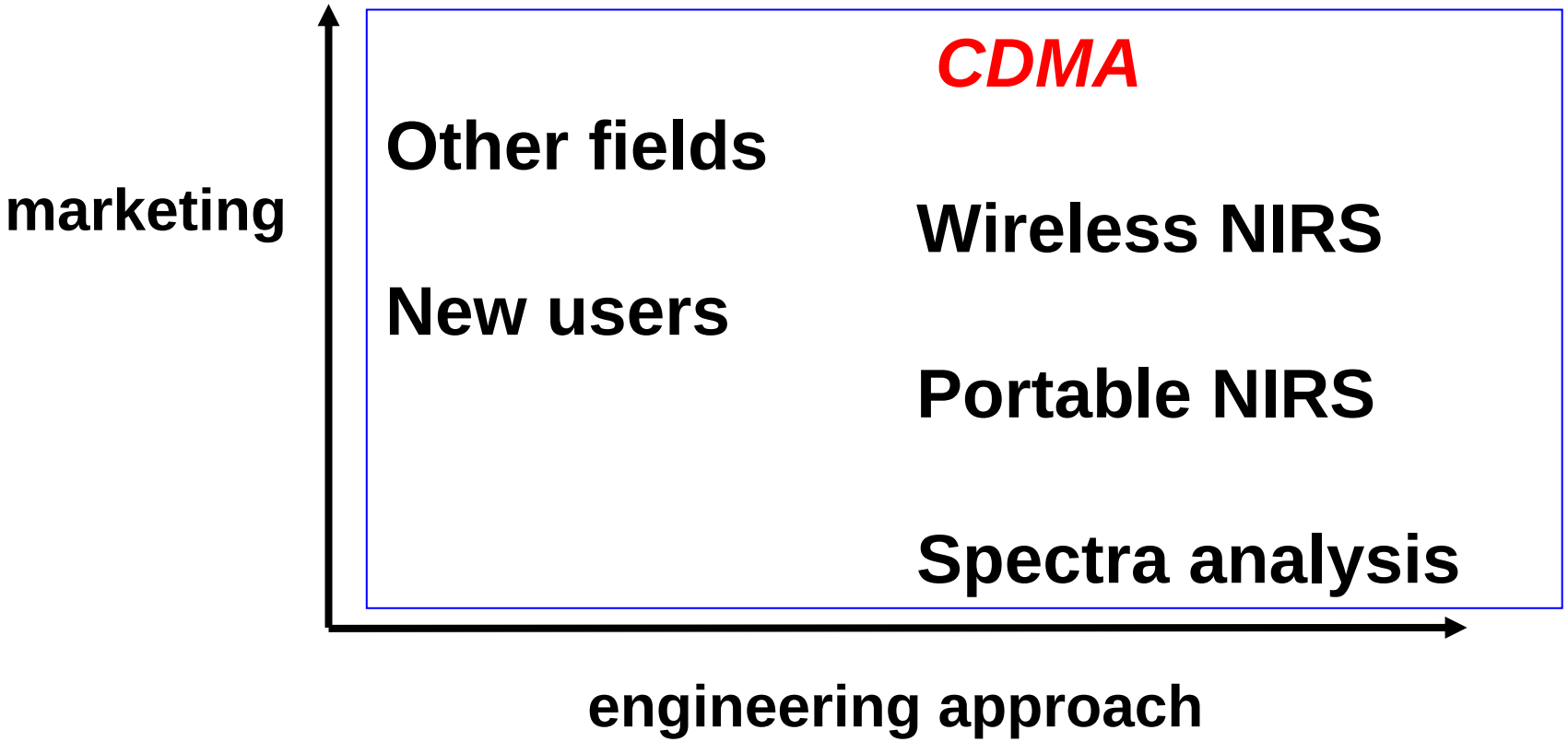
MRI
Lauterbur (1973)

***Project on the Decade of the Brain* (1990)**

fMRI **SPM99**
Ogawa(1992) **UCL (2000)**

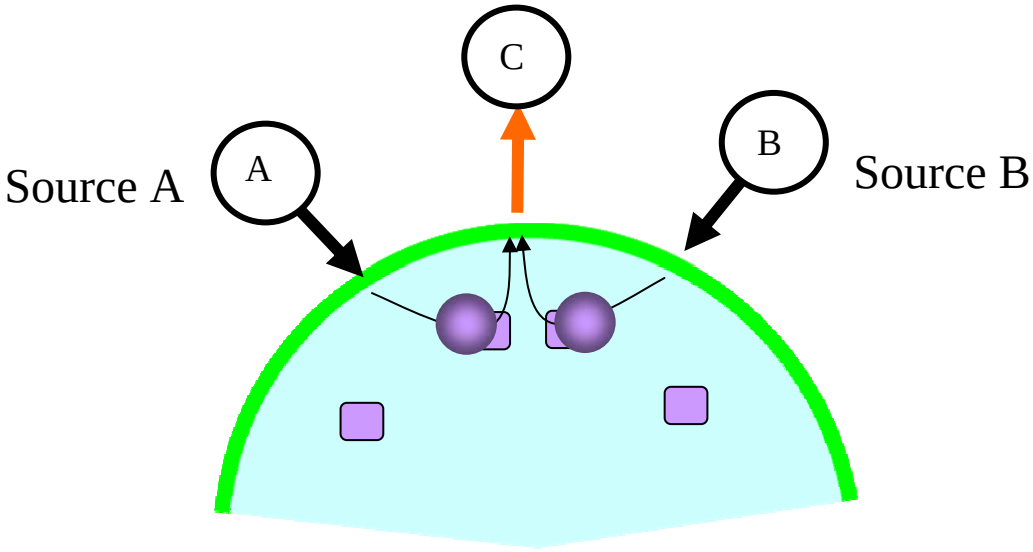
Nobel Prize

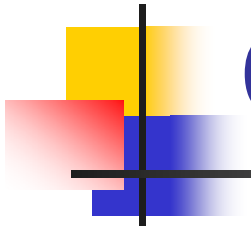
For NIRS breakthrough, think about ‘NIRS Innovation’



Channel separation is needed for NIRS imaging

Detector has to know signal from A or from B.





Channel separation

TDMA（Time Division Multiple Access）

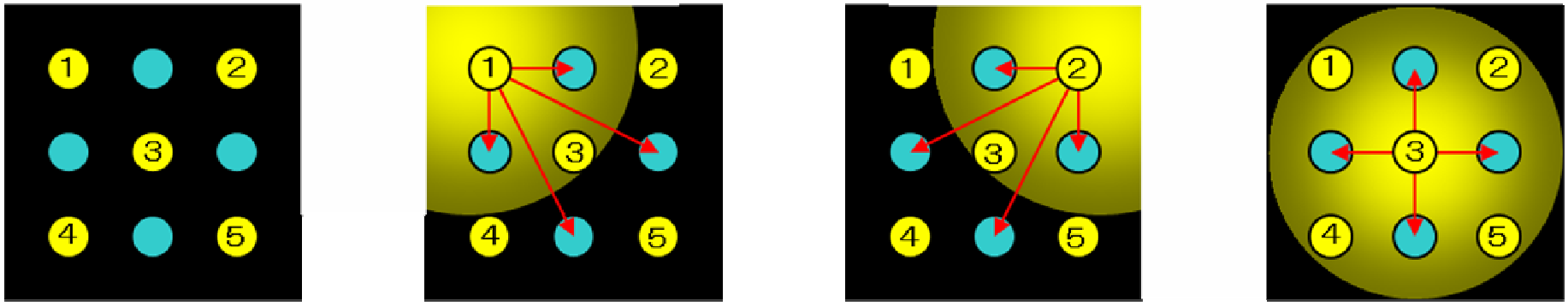
FDMA（Frequency Division Multiple Access）

CDMA（Code Division Multiple Access）

TDMA
Time Division Multiple Access

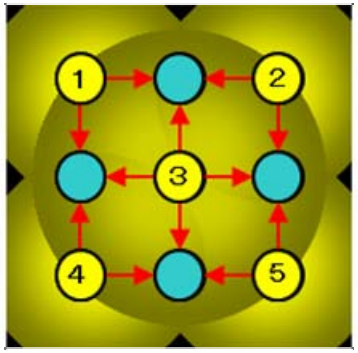
Source

Detector



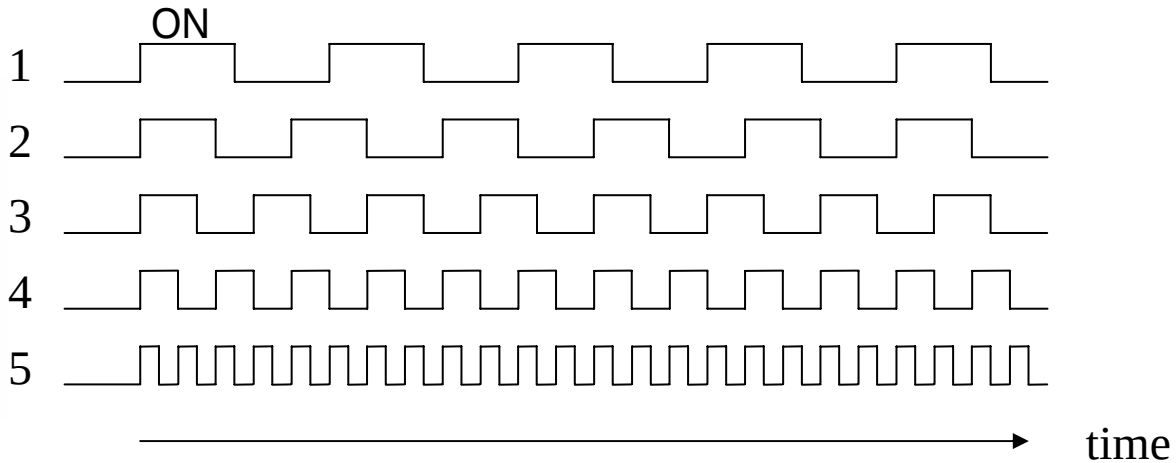
Only one source is ON at the time.

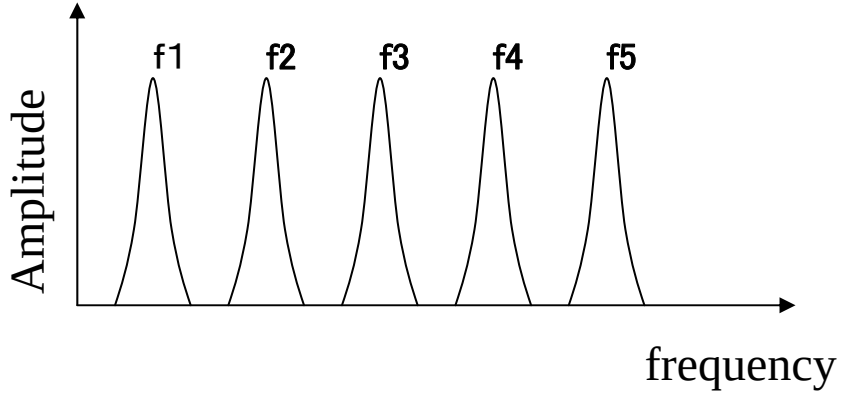
FDMA
Frequency Division Multiple Access

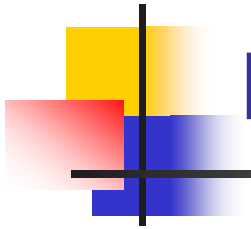


Source

Detector







Brief history of CDMA

1959

J.P.Costas, “Poisson Shannon and the Radio Amateur”

1980

EU: Mobile Phone

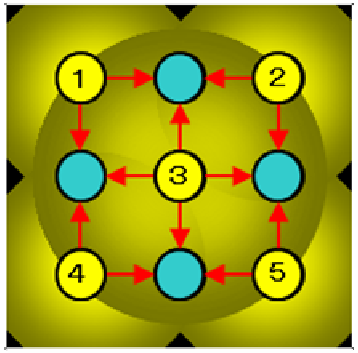
1993

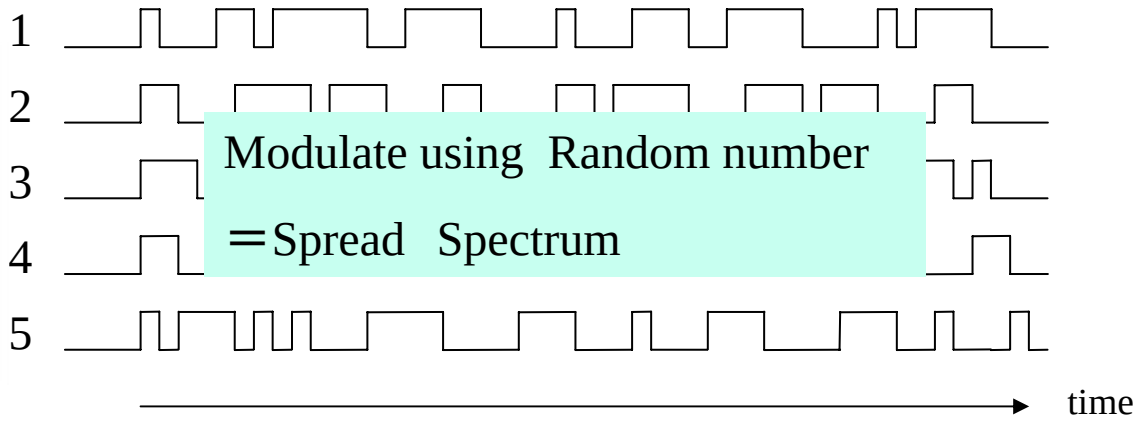
Qualcom(USA); Standard of Digital mobile phone

1993

WaveLAN by NCR(USA) came to Japan.

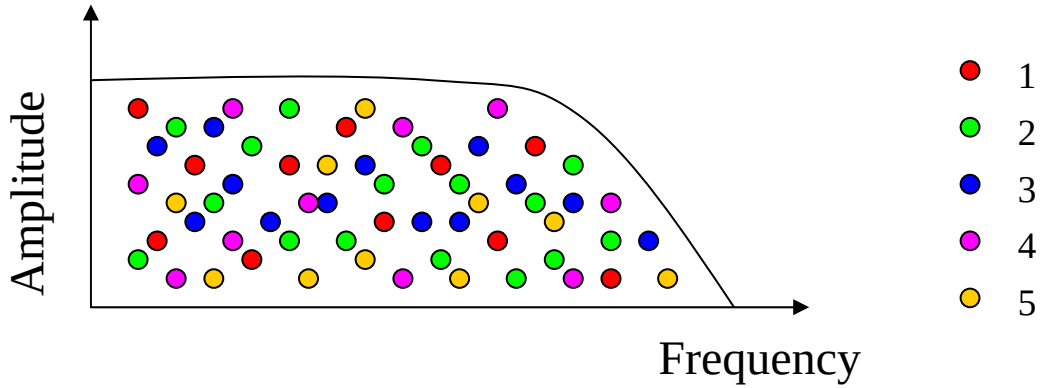
CDMA
Code Division Multiple Access





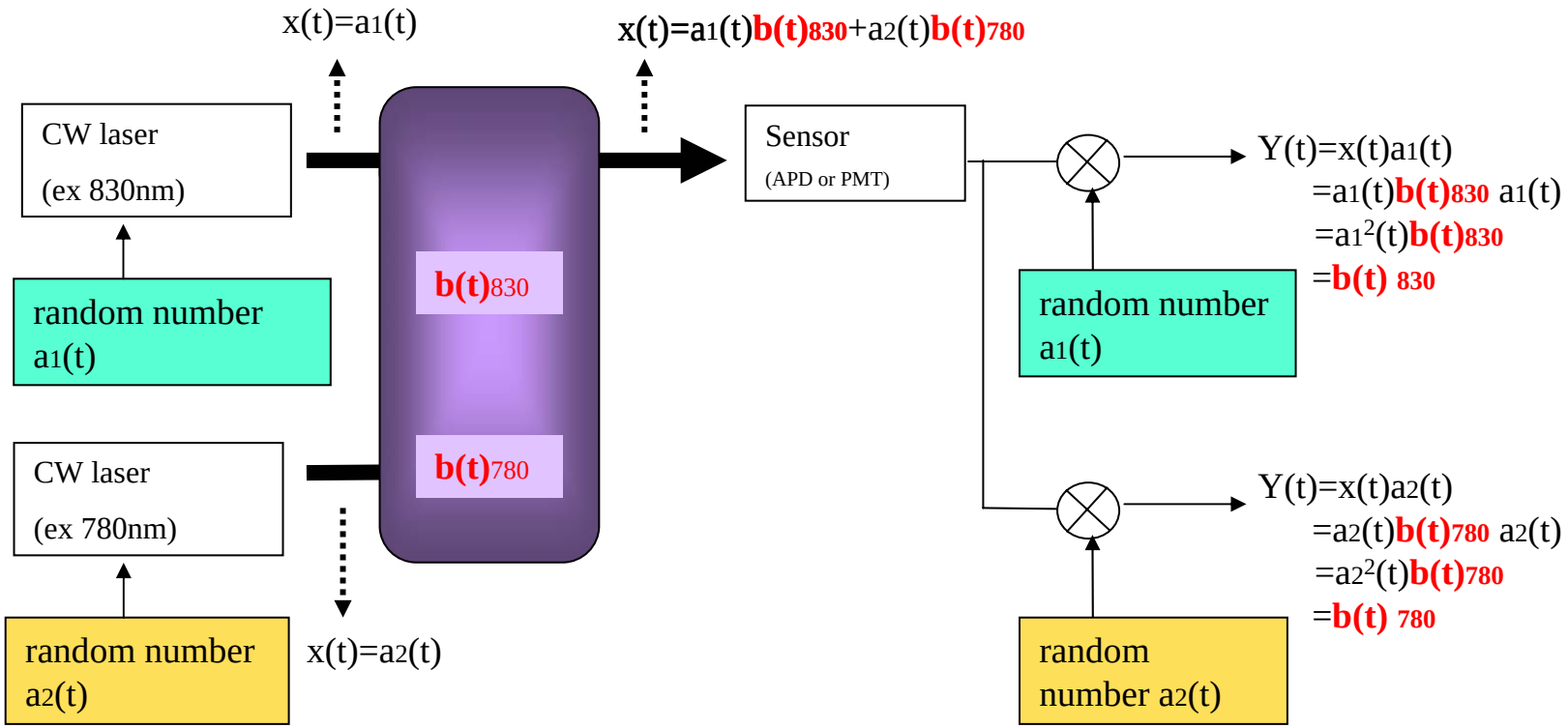
Source

Detector



http://www.spectratech.co.jp/

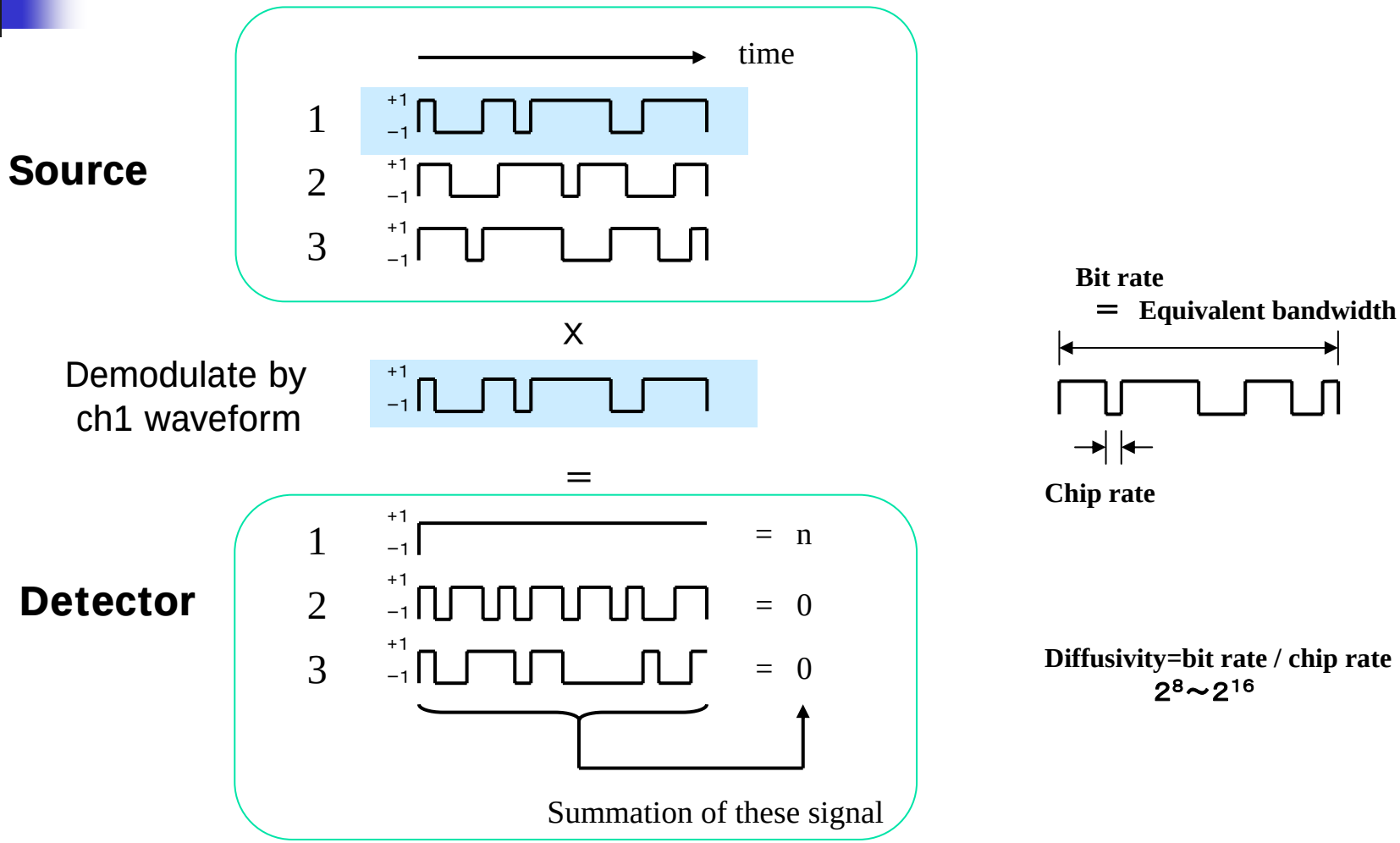
Measure tissue information; b(t)



Random number is called as PIN code.

M-series, Hadamard code, Gold series, etc

CDMA mechanism



Bit rate
＝ Equivalent bandwidth

Chip rate

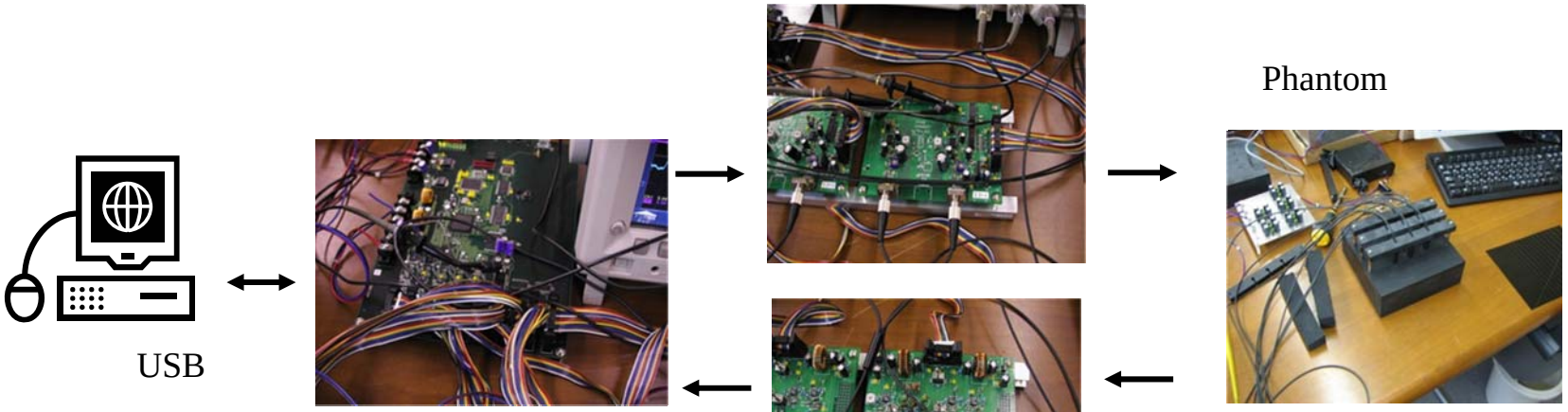
Diffusivity=bit rate / chip rate
$2^8 \sim 2^{16}$

Comparison

	TDMA	FDMA	CDMA
Theory	easy	complicated	difficult
Increase number of Channels	△	○	◎
Simultaneous measurement	△	◎	◎
High SNR	Zone restrictions	Zone restrictions	Some ways
Influence of external noise	Big	Low	Lowest
Hardware	Easy/Small	Complicated/Large	Easy/Small
Examples	Internet packet	Digital broadcasting （13 segment OFDM）	Mobile Phone GPS(Car navigation)

Experimental setup

Laser 12CH （ 4 x 3wavelength ）



Phantom

USB

FDMA modulator 12CH
FDMA demodulator 5CH

CDMA modulator 12CH
CDMA demodulator 60CH

Sensor 5

APD zone 100KHz

PMT zone 1MHz

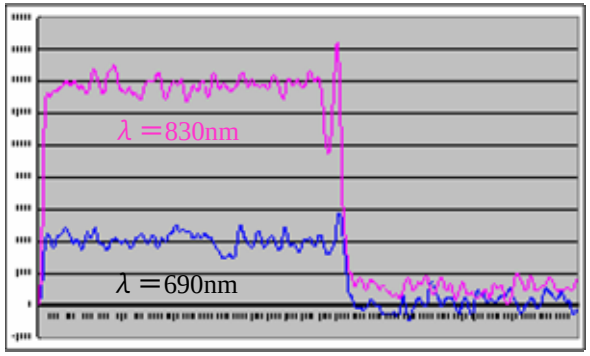
3x3

3mm

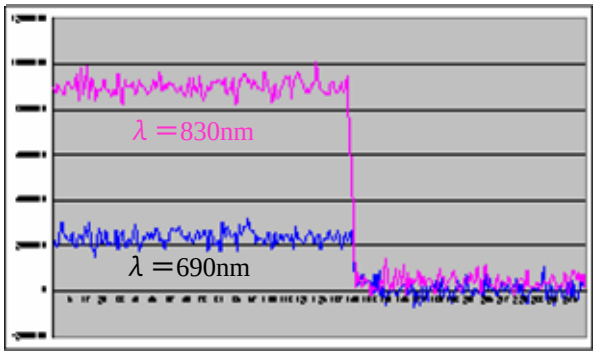
Polyplopilem

Channel separation

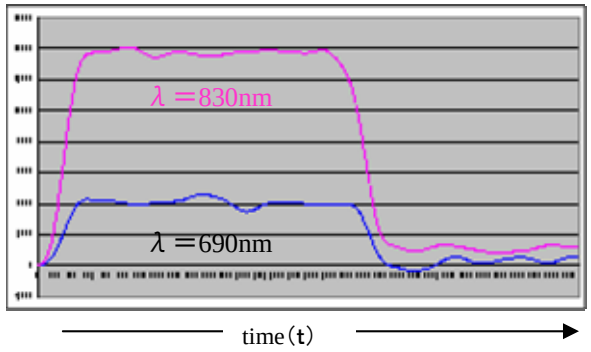
FDMA 10Hz LPF



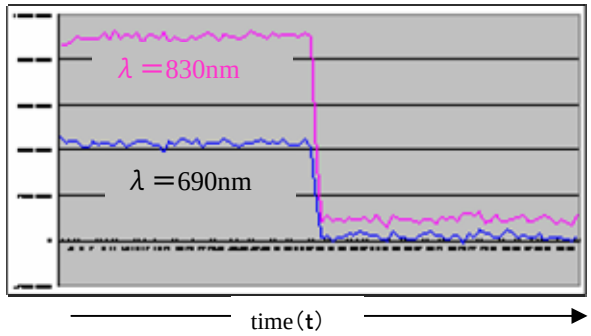
CDMA-2^{12}Bit



FDMA 2Hz LPF



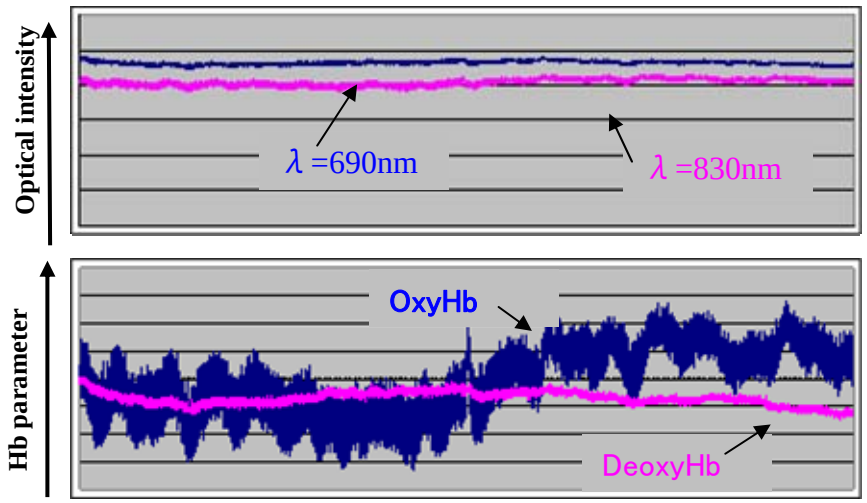
CDMA-2^{16}Bit



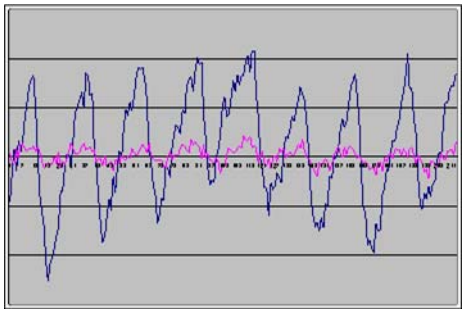
2mW laser output × 10^{-7}

http://www.spectratech.co.jp/

Brain measurement at *rest*



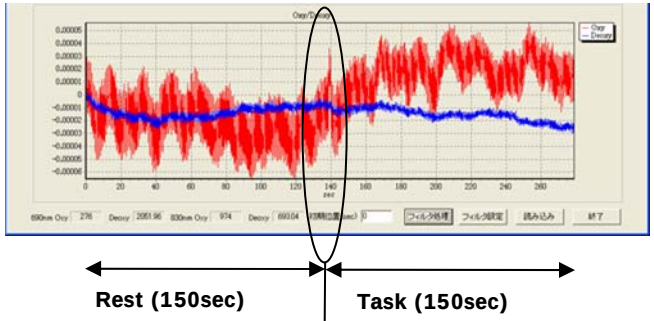
Laser	2mW/830nm +690nm
Chip rate	1MHz
PMT gain	$5x10^6$
Measure time	20 sec
Area	Temporal lobe
bit	2^{15}Bit
Equivalent bandwidth	15 Hz
sampling	33 mS
SNR	49.3 dB

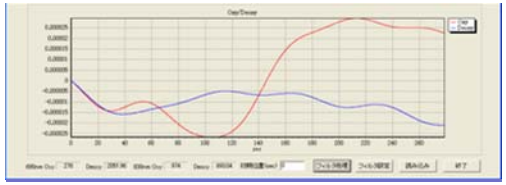


http://www.spectratech.co.jp/

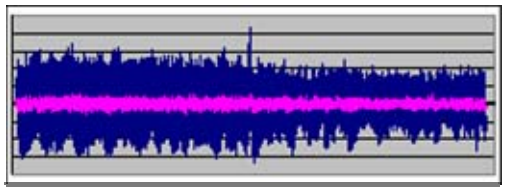
Brain measurement
Nintendo DS Kanji training

Task：NintendoDS
脳を鍛える大人のDSトレーニング漢字問題
Frontal

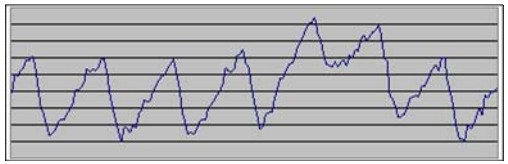




Low ：⊿oxyHb,⊿deoxyHb



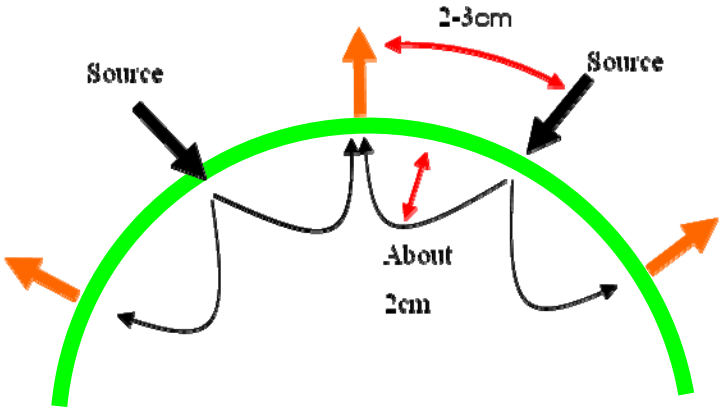
Middle: SO2?



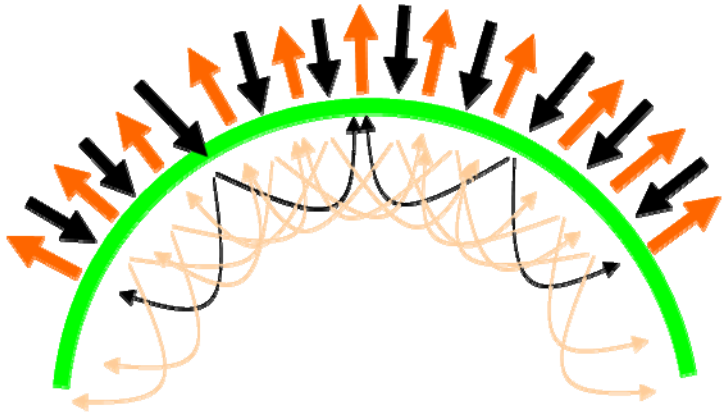
High：Heart Rate

http://www.spectratech.co.jp/

Multiple point detection is easily possible with CDMA

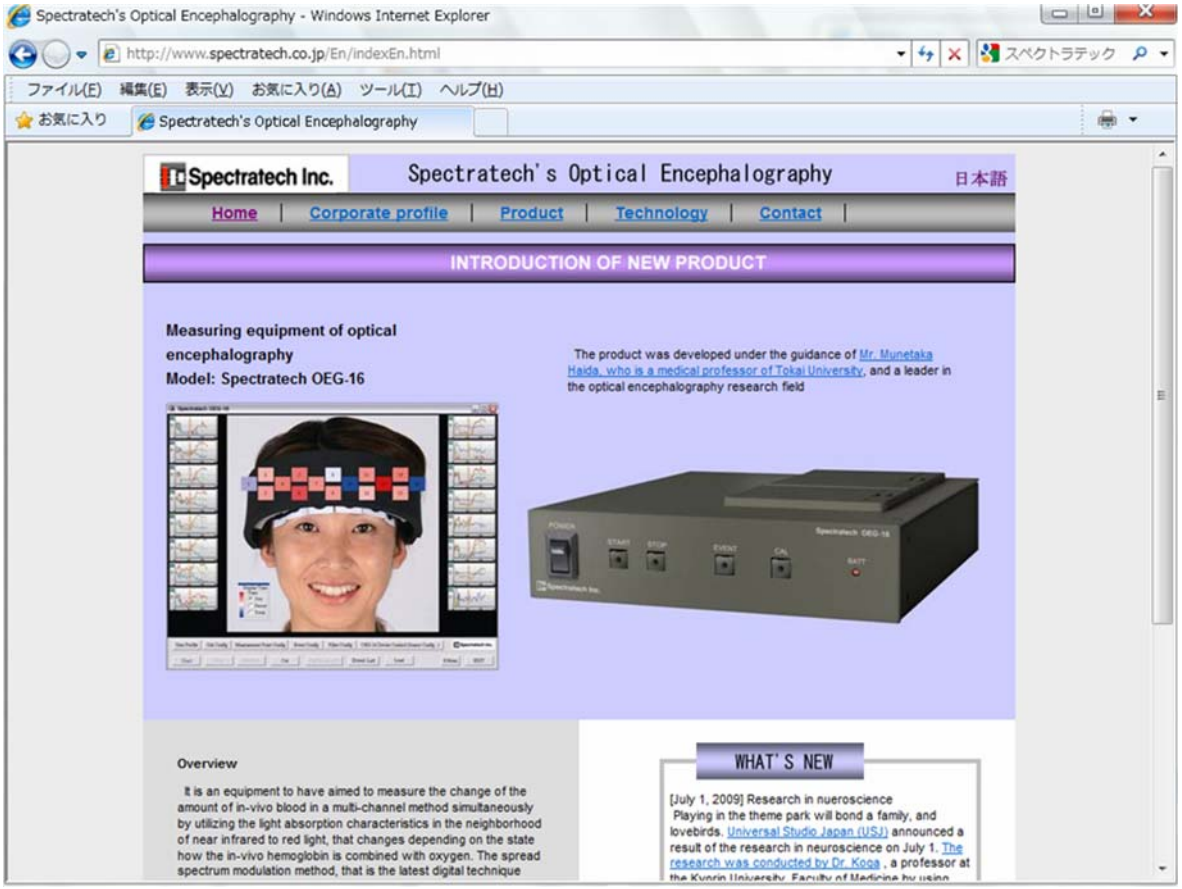


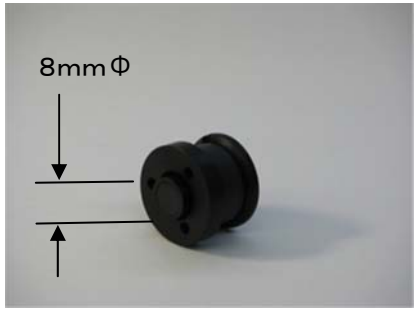
Conventional NIRS



CDMA - NIRS

Spectratech OEG-16
http://www.spectratech.co.jp/

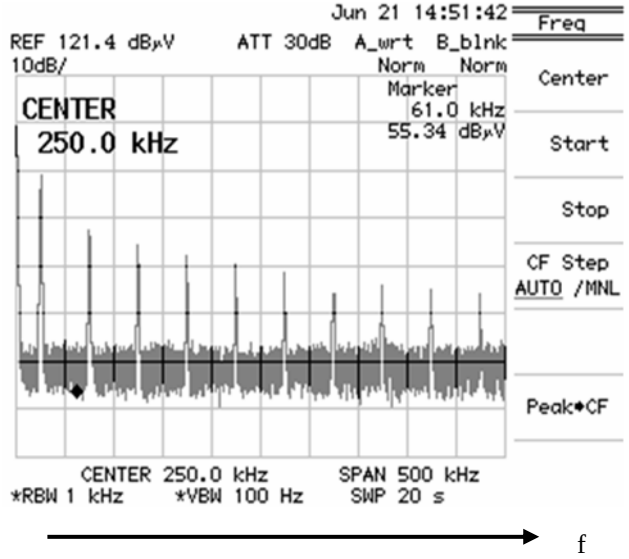




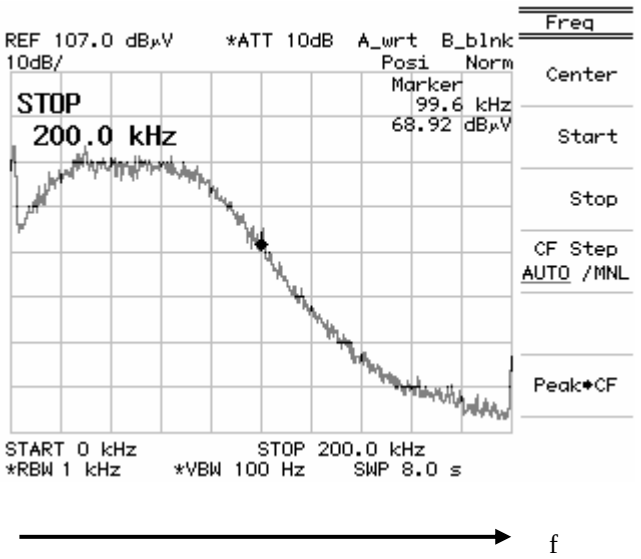
PIN photo diode and Ampliphier

http://www.spectratech.co.jp/

Spectrum of FDMA and CDMA

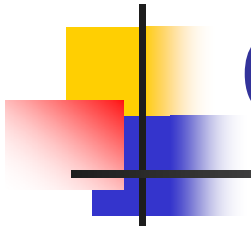


FDMA



CDMA

http://www.spectratech.co.jp/



Conclusion

- NIRS basic and history were described.
- For imaging, Channel separation is important.
- TDMA, FDMA, CDMA can be used for NIRS imaging.
- NIRS using CDMA in now on the market. (http://www.spectratech.co.jp/)