ELEKTRON SPIN

BUKTI EKSPERIMENT TENTANG ADANYA SPIN
FINE STRUKTURE

N

M

L

K

FINE STRUKTURE

SUPER FINE STRUKTURE

HYPER FINE STRUKTURE
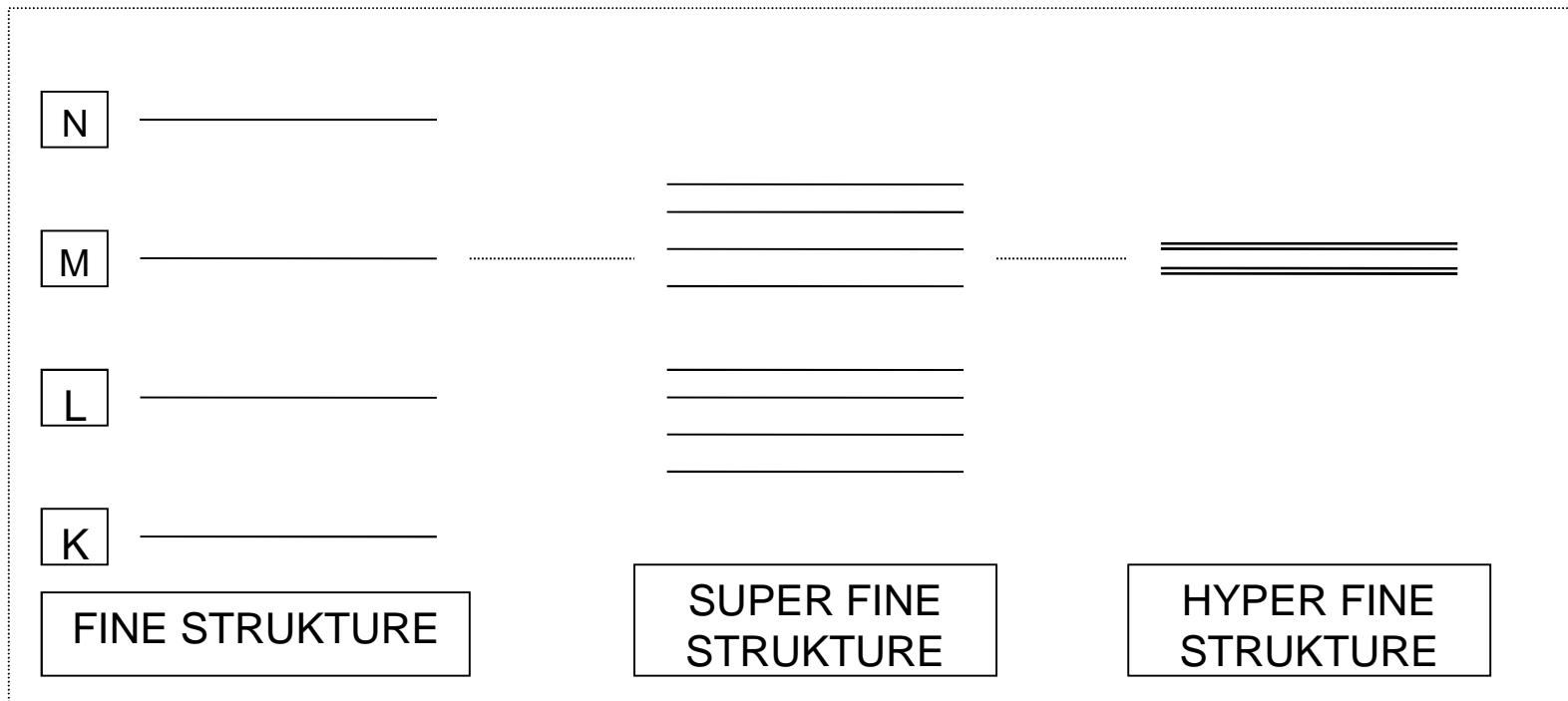
KULIT K	K	L	M	N
n	: 1	2	3	4
l	: 0	0,1	...	(n-1)
s	: $\frac{1}{2}, -\frac{1}{2}$			$\vec{S}$

$$\vec{J} = \vec{L} + \vec{S}$$
$$\left| \vec{J} + \left| l+s \right| ... \left| l+s-1 \right| \right|$$
$$... \left| l-s \right|$$

Contoh :   Kulit M→   n = 3, l = 0,1,2

$$l = 0 \Rightarrow \left|\vec{J}\right| = \frac{1}{2} \Rightarrow m_s = -\frac{1}{2}, +\frac{1}{2}$$

$$l = 1 \Rightarrow \left|\vec{J}\right| = \frac{3}{2} \Rightarrow m_s = -\frac{3}{2}, -\frac{1}{2} +\frac{1}{2}, \frac{3}{2}$$

$$l = 2 \Rightarrow \left|\vec{J}\right| \begin{cases} = \frac{1}{2} \Rightarrow m_s = -\frac{1}{2}, \frac{1}{2} \\ = \frac{5}{2} \Rightarrow m_s = -\frac{5}{2}, -\frac{3}{2}, -\frac{1}{2} +\frac{1}{2}, \frac{3}{2}, \frac{5}{2} \\ = \frac{3}{2} \Rightarrow m_s = -\frac{3}{2}, -\frac{1}{2} +\frac{1}{2}, \frac{3}{2} \end{cases}$$

$$l=0 \ (s) \qquad j=\frac{1}{2} \Rightarrow m_s = 2e$$

$$l=1 \ (p) \qquad j=\frac{1}{2} \Rightarrow m_s = 2e$$

$$l=1 \ (p) \qquad j=\frac{3}{2} \Rightarrow m_s = 4e$$

$$l=2 \ (d) \qquad j=\frac{3}{2} \Rightarrow m_s = 4e$$

$$l=2 \ (d) \qquad j=\frac{5}{2} \Rightarrow m_s = 6e$$

$$J=\frac{1}{2} \qquad l=0 \quad 3$$

l = 1

$$J=\frac{3}{2} \qquad J=\frac{5}{2}$$

l = 2

S = bulat $\Rightarrow$ *partikel boson*

$$S=\frac{1}{2}, bilangan \ ganjil \ \Rightarrow \ fermion \quad J=\frac{1}{2} \qquad l=0$$
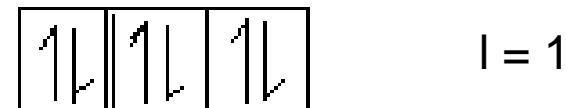
ANOMALI EFEK ZEEMAN

B = 0

$B \neq 0$
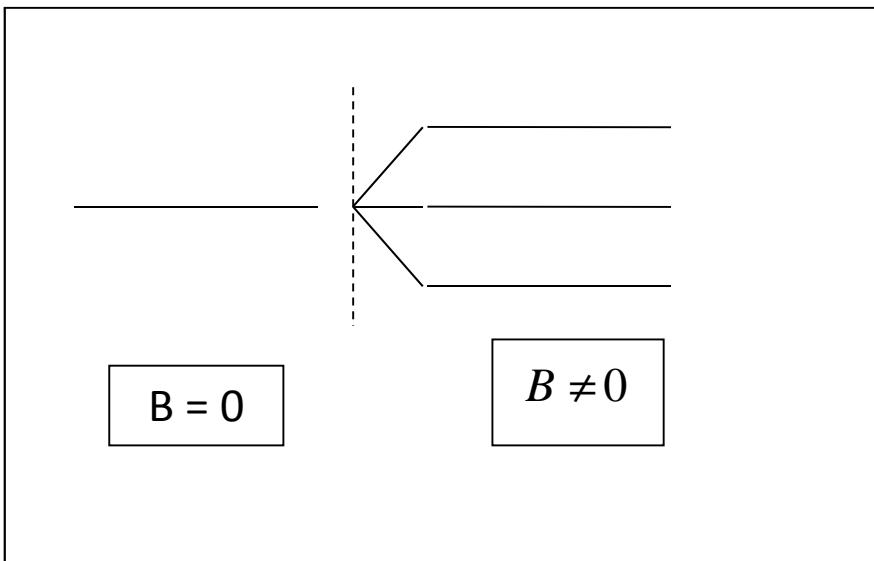
Untuk Z = genap $\Rightarrow$ benar atom akan pecah masuk ke medan B sejumlah bil. Ganjil memperkuat asumsi bahwa l = bulat (efek zeeman normal).

Ganjil $\Rightarrow$ atom pecah bil. Genap $\Rightarrow$ l = bulat.

Tak normal $\Rightarrow$ anomali

Dipengaruhi

$$\vec{B} = efek\ zeeman$$

$$E = efek\ Strake$$

z

y

m_e

+1 0 -1

+1

0

0

0

-1

S

U
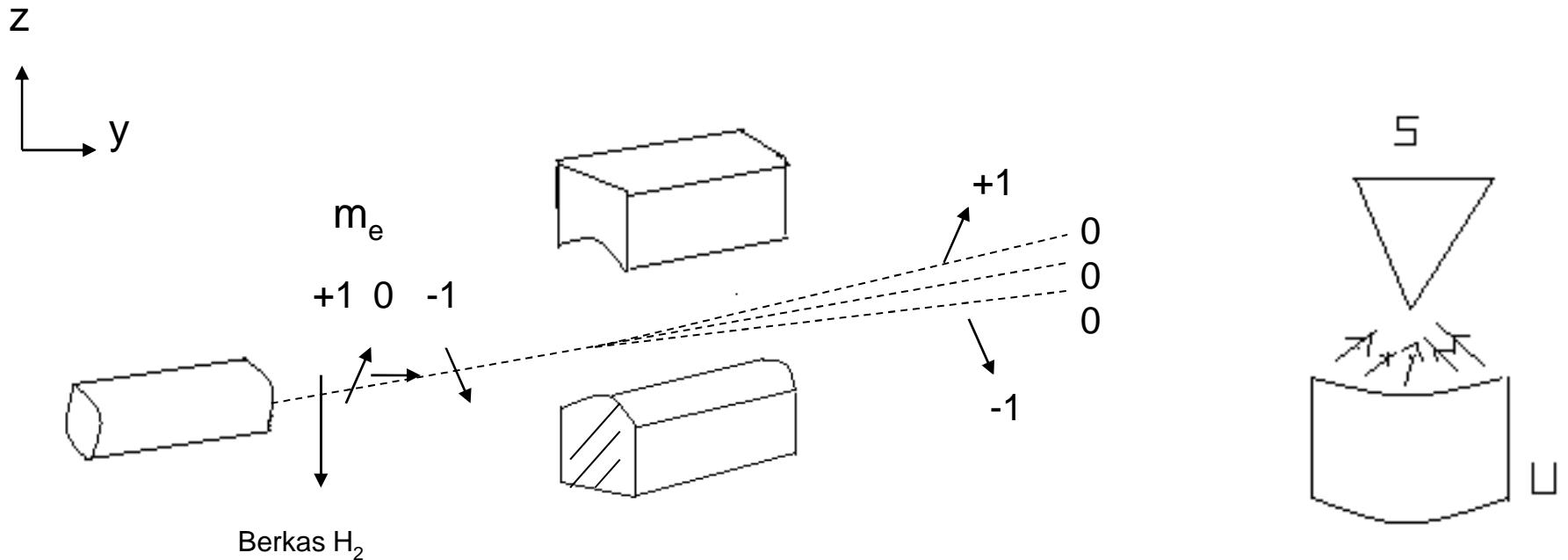
Berkas H$_2$

Seberkas atom dilewatkan dalam daerah yang terdapat $\vec{B}$ $(B_z\,\hat{z})$. Atom-atom dengan arah momen dipole berlawanan mengalami gaya dalam dua arah yang berlawanan.

z

(1)

y

(2)

x
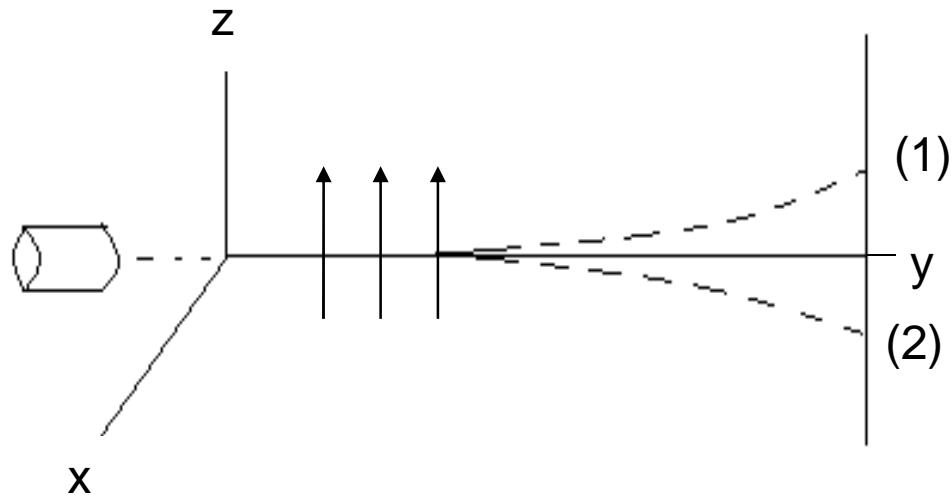
$\vec{M} = \dfrac{\mu B}{\hbar}\vec{L}$ dimana

$\mu = Magneton\,Bohr = \dfrac{q\hbar}{2m_e}$

$\vec{M} = momen\,dipole\,magnet$

$\vec{L} = momentum\,sudut\,orbital$

ANALISIS PERCOBAAN STERN GERLACH

$$|1\rangle = |S_z = +\rangle \; ; \; |2\rangle = |S_z = -\rangle$$

$$|i\rangle = a|S_z = +\rangle + b|S_z = -\rangle$$

$$\langle + | i \rangle = a\langle + | + \rangle + b\langle + | - \rangle = 1$$

$$\langle - | i \rangle = a\langle - | + \rangle + b\langle - | - \rangle = 1$$

$$\boxed{\dfrac{dB}{dZ}}$$

$$\boxed{S}$$

$$|i\rangle$$

$$\boxed{U}$$

$$|i`\rangle$$

$$\boxed{S}$$ $$|f\rangle$$

$$\boxed{U}$$
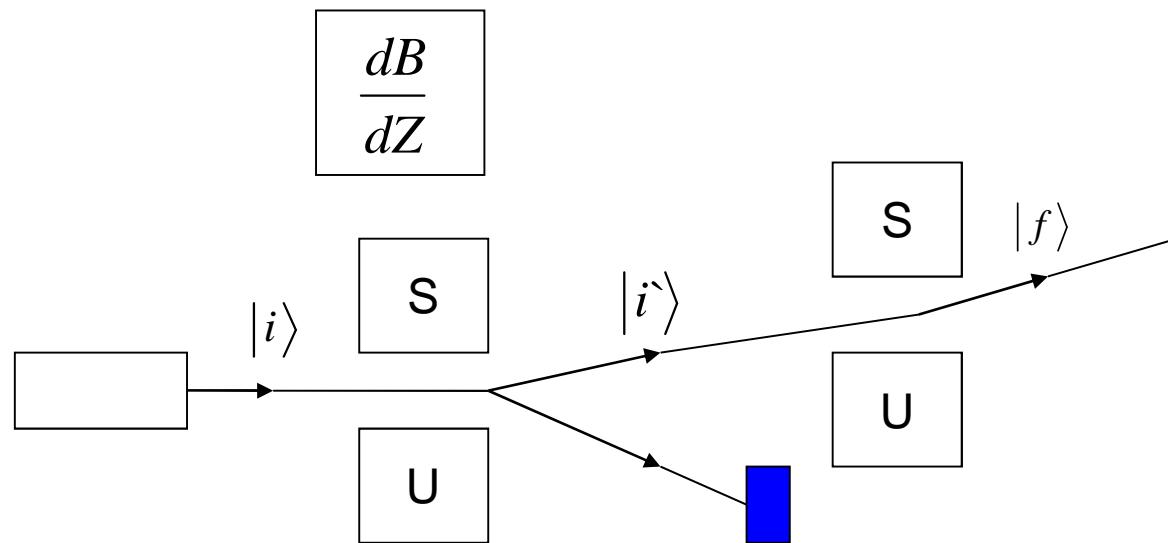
$$\left| \langle + | i \rangle \right|^2 = \left| \langle - | i \rangle \right|^2 \quad \Leftrightarrow \quad \langle + | i \rangle \langle + | i \rangle^{\times} + \langle - | i \rangle \langle - | i \rangle^{\times}$$

Bagaimana jika divais SG yang kedua membentuk sudut α dengan yang pertama?

FILTER STERN GERLACH
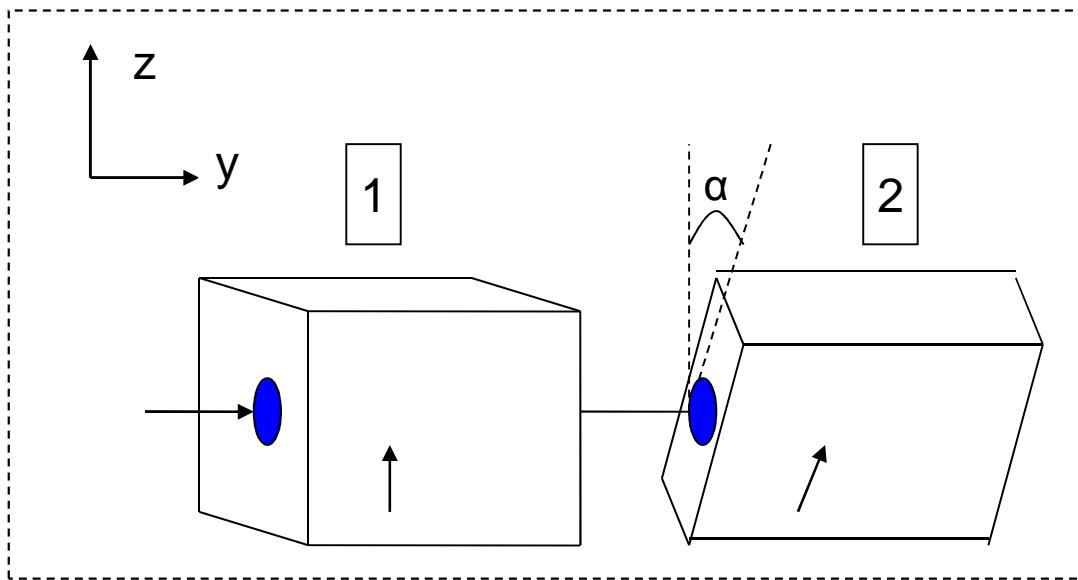
$untuk\_\alpha = 90$

$z \Leftrightarrow x$

$\left|S_x = \pm\right\rangle \neq \left|S_z = \pm\right\rangle$

$filter(1)\left|S_z = +\right\rangle, filter(2) = \left|S_x = -\right\rangle$

$\left\langle S_x = + \middle| S_z = +\right\rangle = \neq 0 \, dan$

$\left\langle S_x = - \middle| S_z = +\right\rangle = \neq 0$

$$\left\langle S_z = + \middle| S_x = -\right\rangle \left\langle S_x = - \middle| S_z = +\right\rangle + \left\langle S_z = - \middle| S_x = -\right\rangle \left\langle S_x = - \middle| S_z = +\right\rangle$$

OPERATOR DAN MATRIKS

Berkas electron mula-mula $|i\rangle$ melewati divais SG menjadi $|f\rangle$. Amplitude proses $\langle f|A|i\rangle$; A = operator sebagai representasi proses dalam divais SG

$$\langle f|A|i\rangle = \sum_{\alpha,\beta} \langle f|\alpha\rangle\langle\alpha|A|\beta\rangle\langle\beta|i\rangle$$

$\langle\alpha|A|\beta\rangle$ *dengan element matriks A*

	$|S_z=+\rangle$	$|S_z=-\rangle$	
$|S_z=+\rangle$	$\langle S_z=+|A|S_z=+\rangle$	$\langle S_z=+|A|S_z=-\rangle$	$\begin{bmatrix} \dfrac{\hbar}{2} & 0 \\ 0 & \dfrac{\hbar}{2} \end{bmatrix}$
$|S_z=-\rangle$	$\langle S_z=-|A|S_z=+\rangle$	$\langle S_z=-|A|S_z=-\rangle$	

Matriks S_y dan S_x dan solusi persamaan eigen

$$|S_x=\pm\rangle = \frac{1}{\sqrt{2}}\left\{|S_z=+\rangle \pm |S_z=-\rangle\right\}$$

$$[S_x,S_y] = \hbar\, S_z \qquad x,y,z\ silidik$$

$$|S_y=\pm\rangle = \frac{1}{\sqrt{2}}-\left\{|S_z=+\rangle \pm i|S_z=-\rangle\right\}$$

Ruang keadaan spin $|s,m\rangle$ *dengan*
$$S^2|s,m\rangle = s(s+1)\hbar^2|s,m\rangle$$
$$S_z|s,m\rangle = m\hbar|s,m\rangle$$

$$S_+ = S_x + iS_y \quad ; \quad S_- = S_x - iS_y \quad ; \quad \Rightarrow \quad S_x = \frac{1}{2}(S_+ + S_-) \quad ; \quad S_y = \frac{1}{2i}(S_+ + S_-)$$

$$S_x|i\rangle = v|i\rangle \quad \Rightarrow \quad \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}\begin{pmatrix} a \\ b \end{pmatrix} = \lambda\begin{pmatrix} a \\ b \end{pmatrix}$$

$$\begin{bmatrix} -\dfrac{2\lambda}{\hbar} & 0 \\ 0 & -\dfrac{2\lambda}{\hbar} \end{bmatrix} = 0 \Rightarrow v = \pm\frac{\hbar}{2} \qquad \rightarrow a = b = \frac{1}{\sqrt{2}} \qquad\qquad a = -b = -\frac{1}{\sqrt{2}}$$

$$+\frac{1}{2}\frac{\hbar}{2} \qquad dan \qquad -\frac{1}{2}\hbar \quad \rightarrow \quad nilai \ \ eigen$$

$$\begin{pmatrix} \dfrac{1}{\sqrt{2}} \\ \dfrac{1}{\sqrt{2}} \end{pmatrix} dan \begin{pmatrix} -\dfrac{1}{\sqrt{2}} \\ \dfrac{1}{\sqrt{2}} \end{pmatrix} \rightarrow spinor \ eigen$$

MATRIKS PAULI

$$S_X = \frac{1}{2}\hbar\sigma_X \quad : \quad S_Y = \frac{1}{2}\hbar\sigma_Y \qquad S_Z = \frac{1}{2}\hbar\sigma_Z \qquad dengan$$

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \quad ; \quad \sigma_y = \begin{pmatrix} 0 & -i \\ 1 & 0 \end{pmatrix} \quad ; \quad \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

$$\sigma_i^2 = I \quad ; \quad \sigma_i\sigma_j + \sigma_j\sigma_i = 2\sigma_{ij}I \quad ; \quad [\sigma_x, \sigma_y] = 2i\sigma_z$$

$$\vec{S} = \hbar\frac{\vec{\sigma}}{2} \quad \rightarrow \quad \sigma^2 = 3 \quad \rightarrow \quad S^2 = \frac{\hbar^2\sigma^2}{4} = s(s+1)\hbar^2 = \frac{3}{4}\hbar^2$$

TRANSFORMASI MATRIKS

Satu filter SG disusun dalam keadaan $|S_z = \alpha\rangle$ yang lain diukur sehingga $|\langle S_y = i | S_z = \alpha\rangle|^2$ mendapatkan berkas keadaan S_y. semua data exp. yang mungkin diberikan oleh element-element yang dinamakan matrik transformasi.