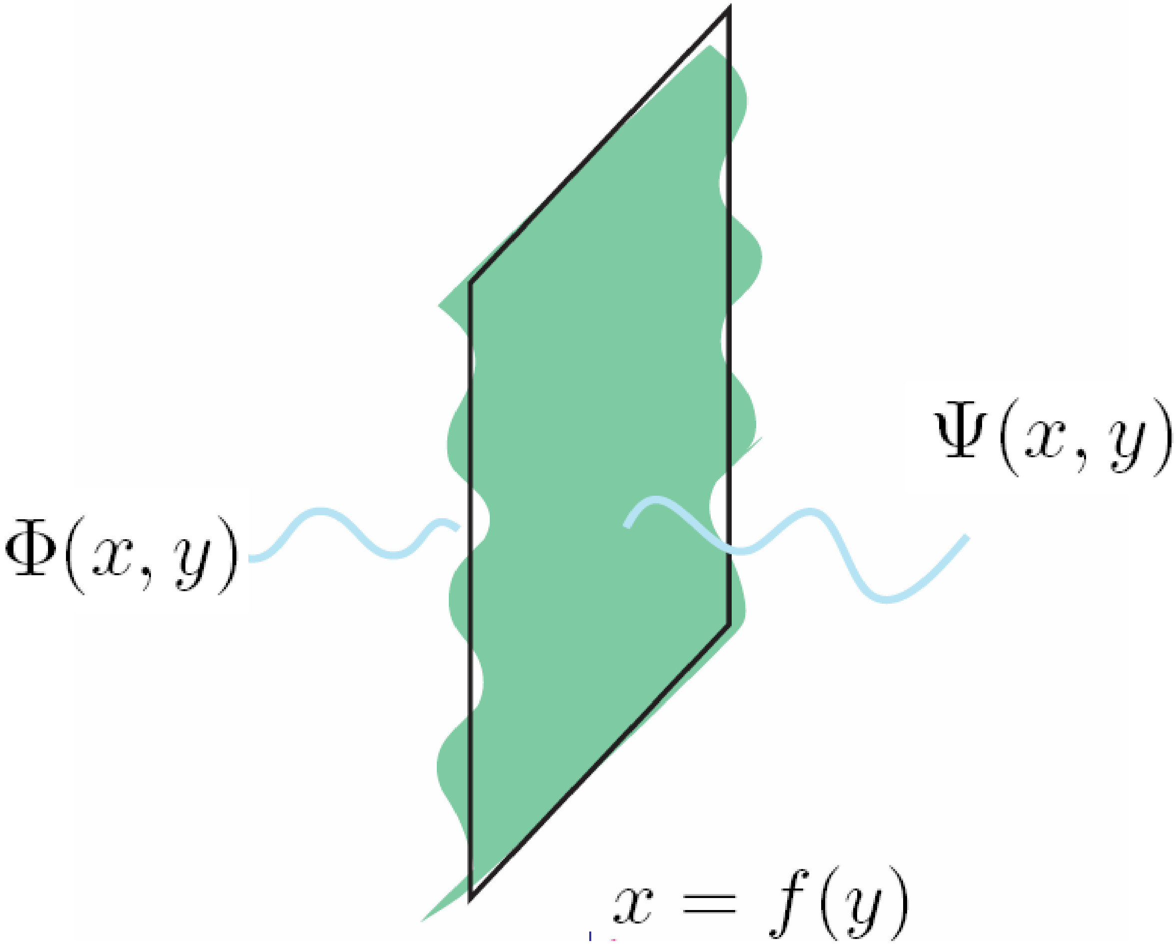
Interlayer Exchange Coupling & Boundary Perturbation

張景皓 4/1 2008

Roughness Perturbation Method:

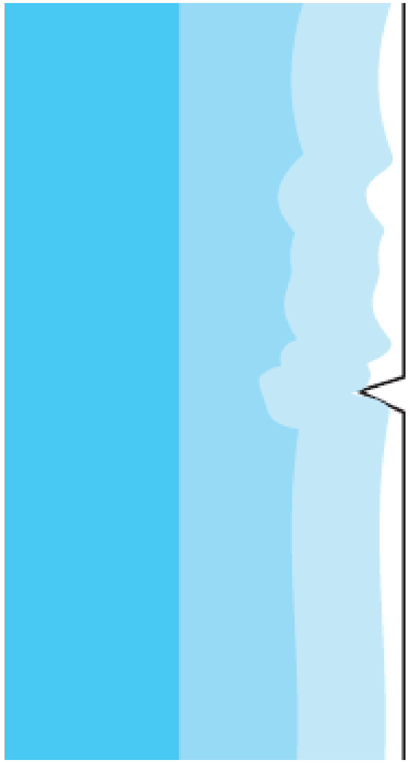


Perturbation Wavefunctions:

$$\Phi(x,y) = \Phi_o(x,y) + \sum_{\vec{q}} a_{\vec{q}} e^{-iq_x x + iq_y y}$$

$$\Psi(x,y) = \Psi_o(x,y) + \sum_{\vec{q'}} b_{\vec{q'}} e^{iq_x^{'} x + iq_y y}$$

Expanding order : $|k_x f(y)|$



極限: (震幅/ 波長) > 1/(2Pi)

$$\Phi(x,y) \approx \frac{1}{2} e^{ik_x \frac{d_o}{2}} \Phi_o(x - d_o/2, y) + \frac{1}{2} e^{-ik_x \frac{d_o}{2}} \Phi_o(x + d_o/2, y)$$

$$+ \sum_i a_{q_{yi}}^{(1)} e^{-iq_{xi}x + i(k_y \pm \omega_i)y}$$

$$\Psi(x,y) \approx \frac{1}{2} e^{ik_x \frac{d_o}{2}} \Psi_o(x - d_o/2, y) + \frac{1}{2} e^{-ik_x \frac{d_o}{2}} \Psi_o(x + d_o/2, y)$$

$$+ \sum_i a_{q_{yi}}^{(1)} e^{iq'_{xi}x + i(k_y \pm \omega_i)y}$$

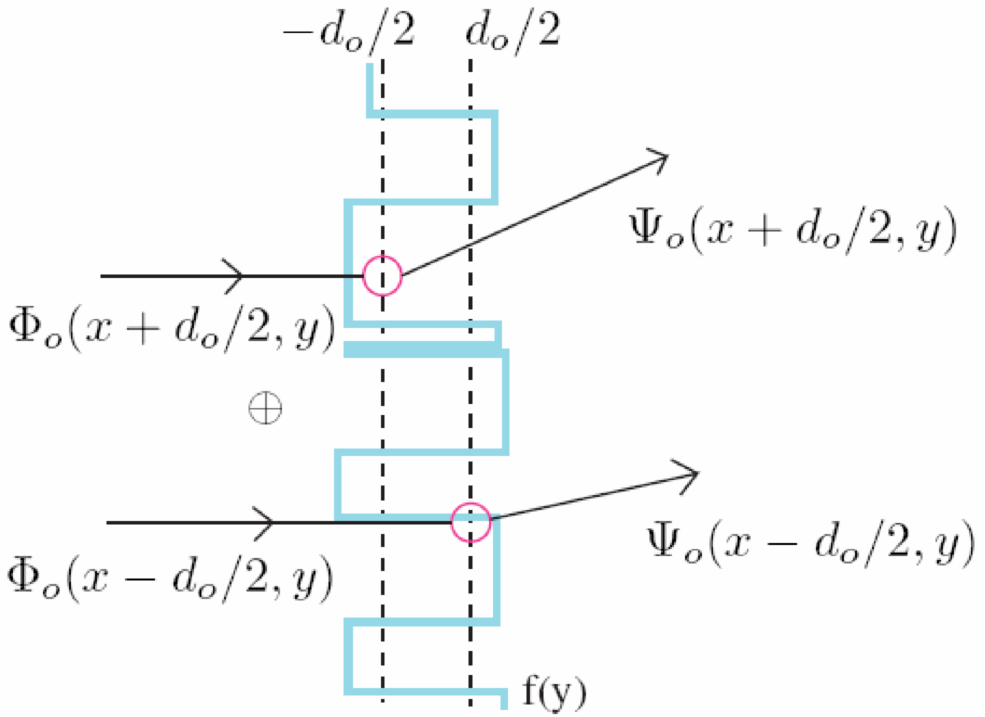
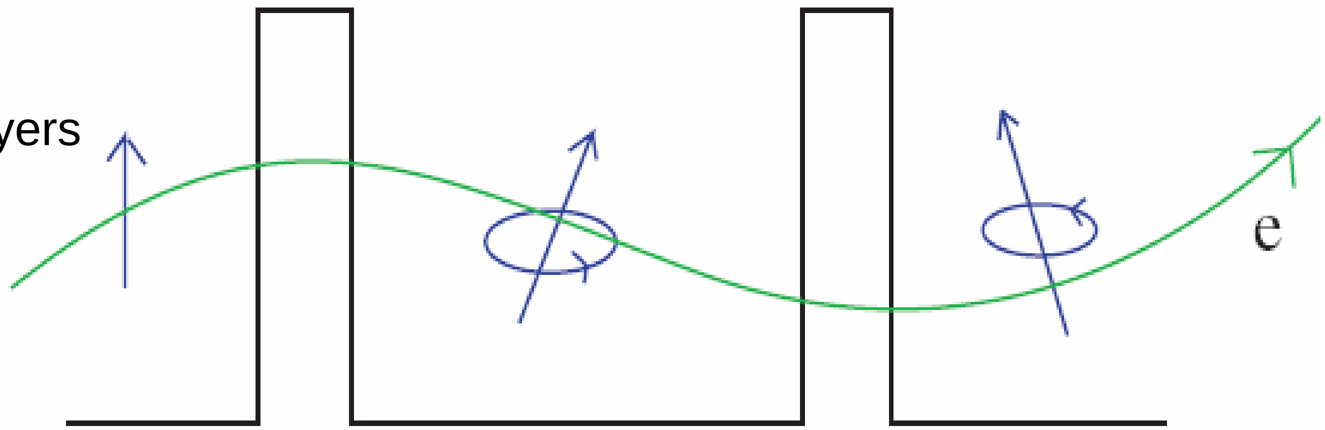


Fig 2: As a planewave be scattered by a seriously rough interface, the process finally could be simplified as a linear combination of two kinds scattering processes.

Interlayer exchange coupling

P. Bruno, PRB,52,00411 (1995)



$$\Delta E_{\mathrm{qw}} = -\int_{-\infty}^{E_{\mathrm{F}}} dE(E - E_{\mathrm{F}})\Delta n(E, D)$$

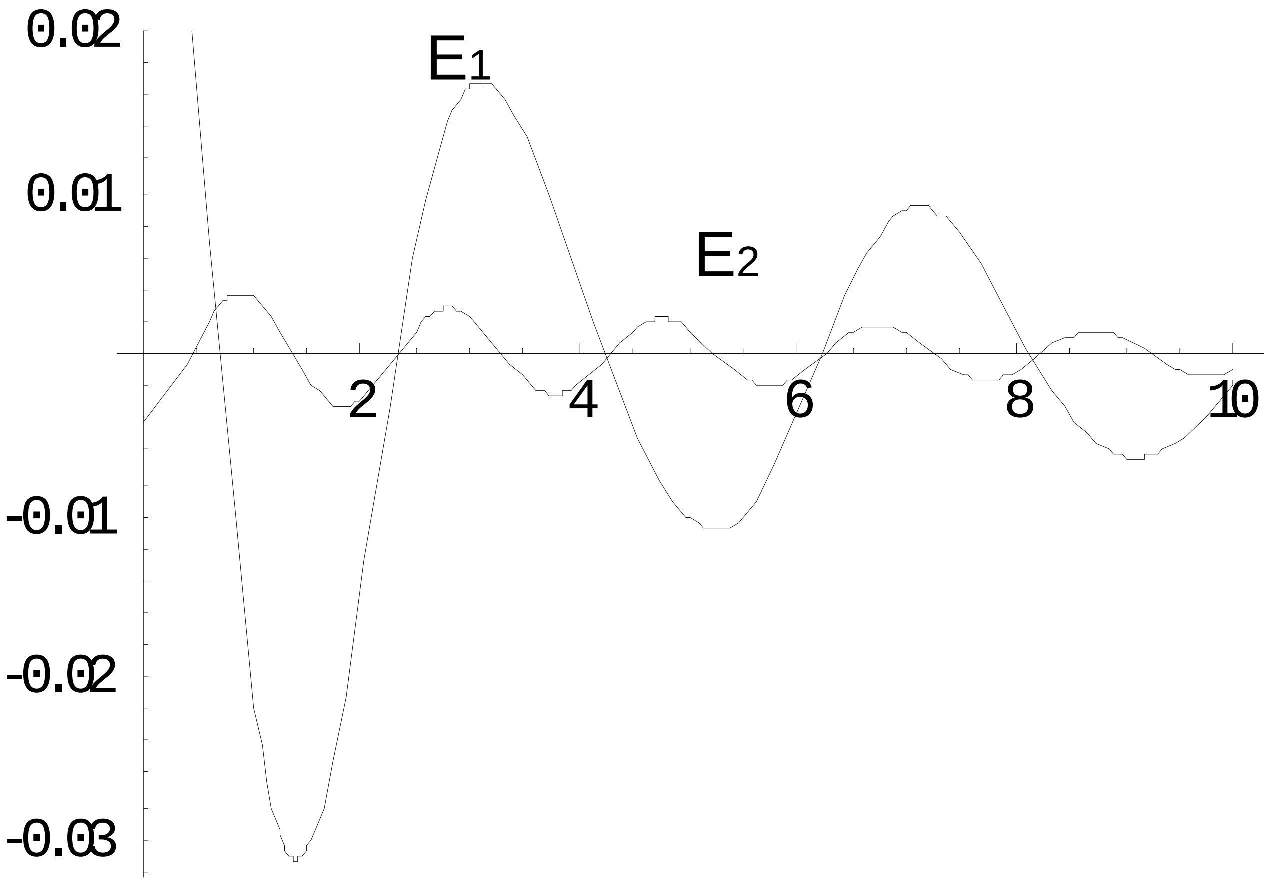
Above result could be realized as:

$$k_F D \gg 1$$

$$\triangle E \approx \frac{1}{2\pi k_F D} \sum_n \frac{1}{n} \mathrm{Re}[(R_A(k_F)R_B(k_F))^n e^{i2k_F nD}]$$

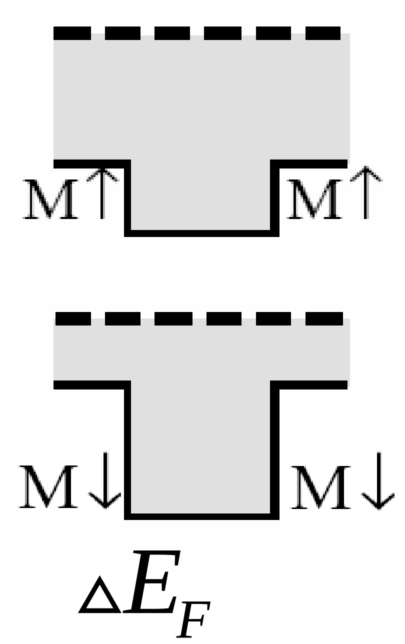
n represent the “order” of coupling energy

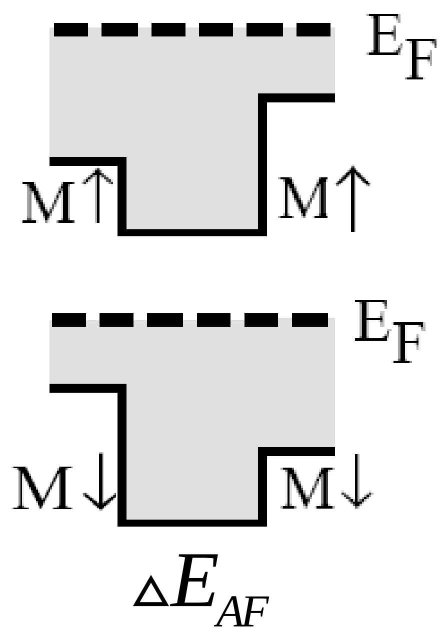
n=1, similar to RKKY coupling


0.02
0.01
-0.01
-0.02
-0.03
2
4
6
8
10
E1
E2

Parallel Alignment

Antiparallel alignment

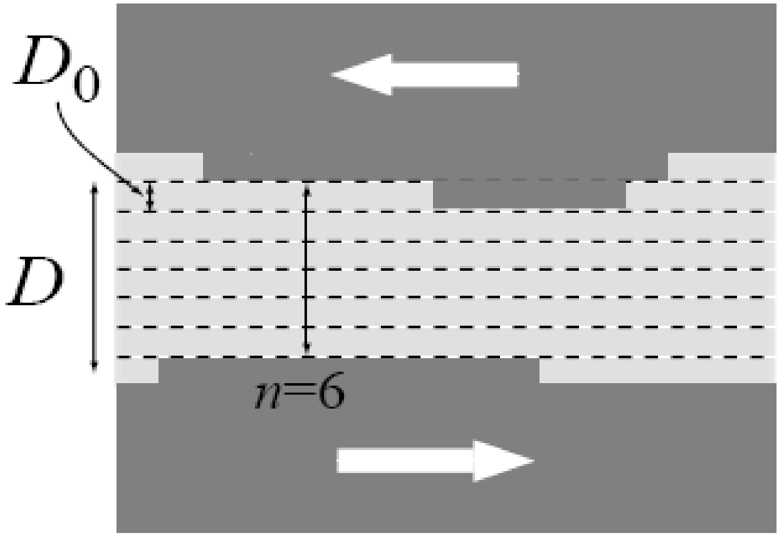




Magnetic films coupling defined as: $(\Delta E_F - \Delta E_{AF})$

Thickness Fluctuation

Thickness Fluctuations



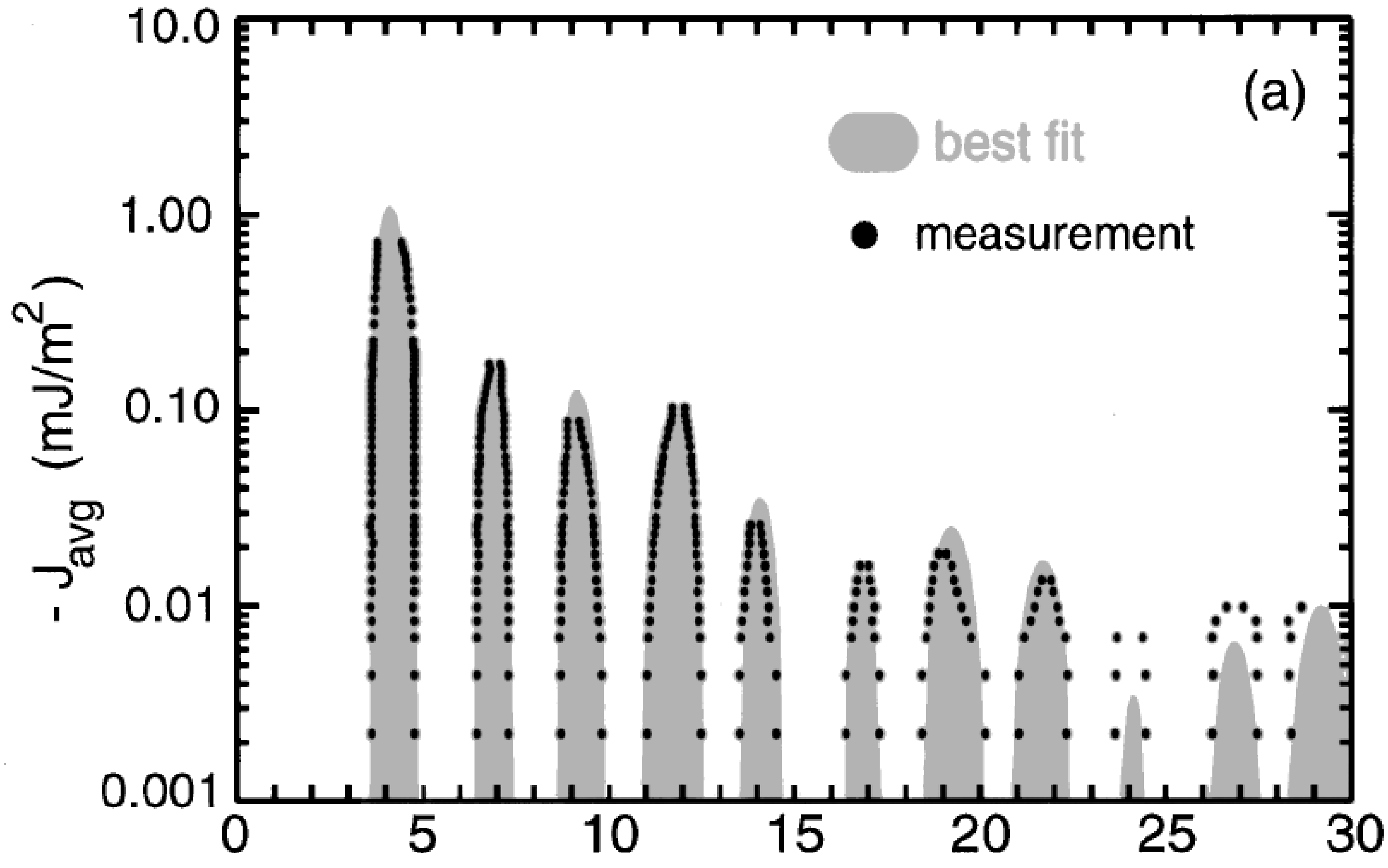
$$J(D) = \sum_n P(n, D) J(n)$$

Interlayer Exchange Coupling

M. D. Stiles

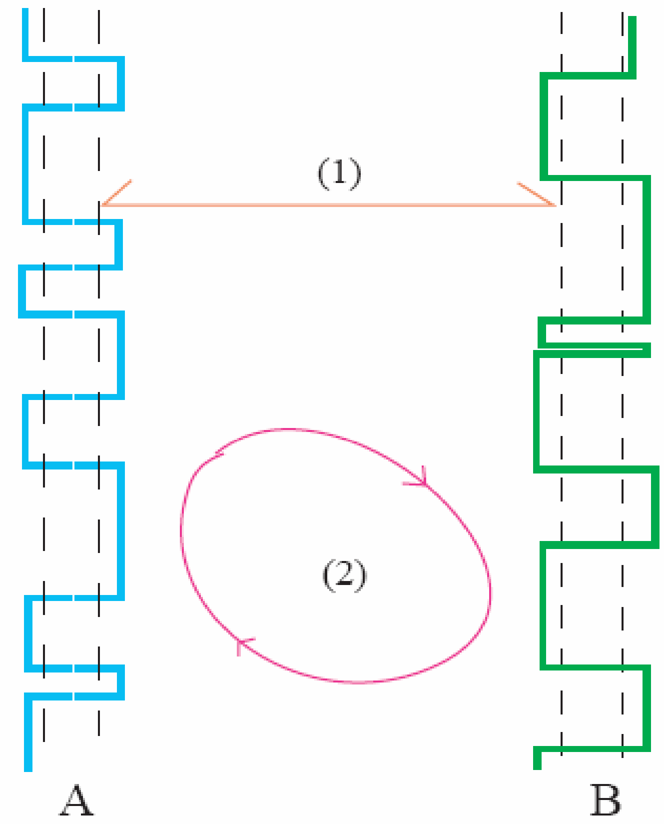
October 31, 2002

There had been progress toward addressing two issues complicating the comparison between theory and exper
nent. One complication is the significant disorder that is present in real systems but absent in theoretical models. Fo
one form of disorder, namely thickness fluctuations, averaging the interlayer exchange coupling over the growth fron
had been proposed [30] as a solution. Unfortunately, the growth front had not been measured and this correctio
had not been made quantitative. Progress on treating other types of disorder, like interdiffusion, was still to com



J. Unguris, R. J. Celotta, and D. T. Pierce, PRL **79** 2734(1997)

Apply our theory on interlayer coupling



$$\triangle E^r_{qi} = \frac{1}{4\pi^3} Im \int_{-\infty}^{E_F} dE \int_{IBZ} d^2\vec{k}_{\|}$$

$$\{-\sum_{n\leq 3} \frac{1}{n} r_A^n (1 - d_A^2 k_\perp^2)^n r_B^n (1 - d_B^2 k_\perp^2)^n e^{2ink_\perp D}$$

$$+ \sum_{q_y} b_A^{(1)}(k_y \rightarrow q_y) b_B^{(1)}(q_y \rightarrow k_y) e^{i[k_\perp(q_y)+k_\perp(k_y)]D}$$

$$+ O[(n+\epsilon) > 3]\} \qquad (22)$$

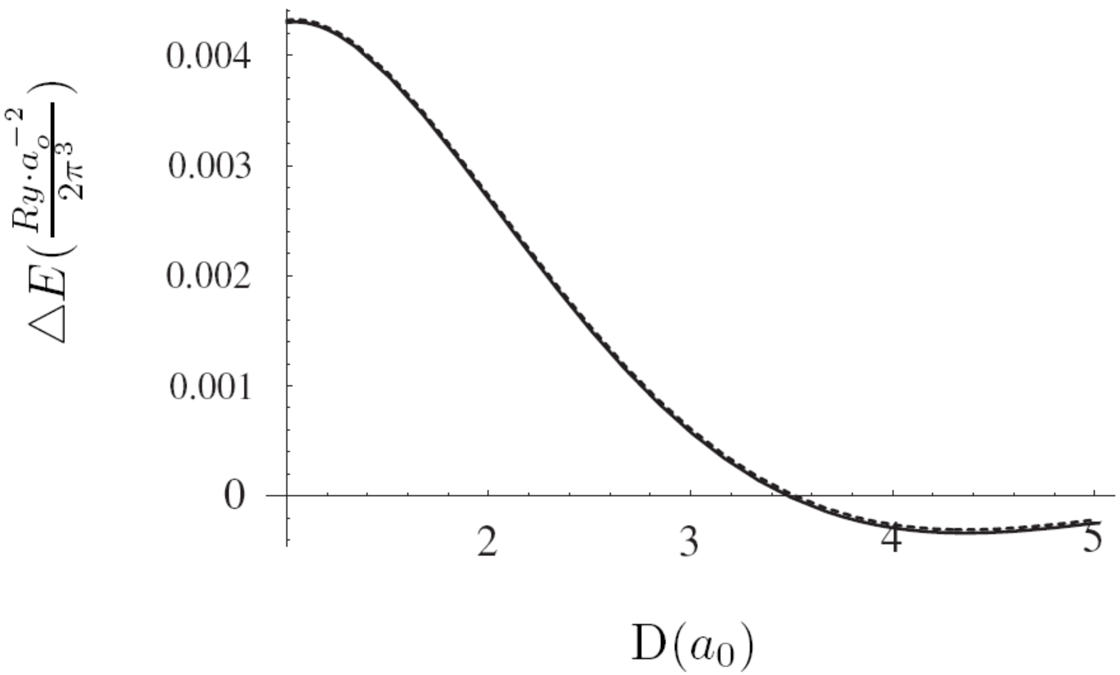
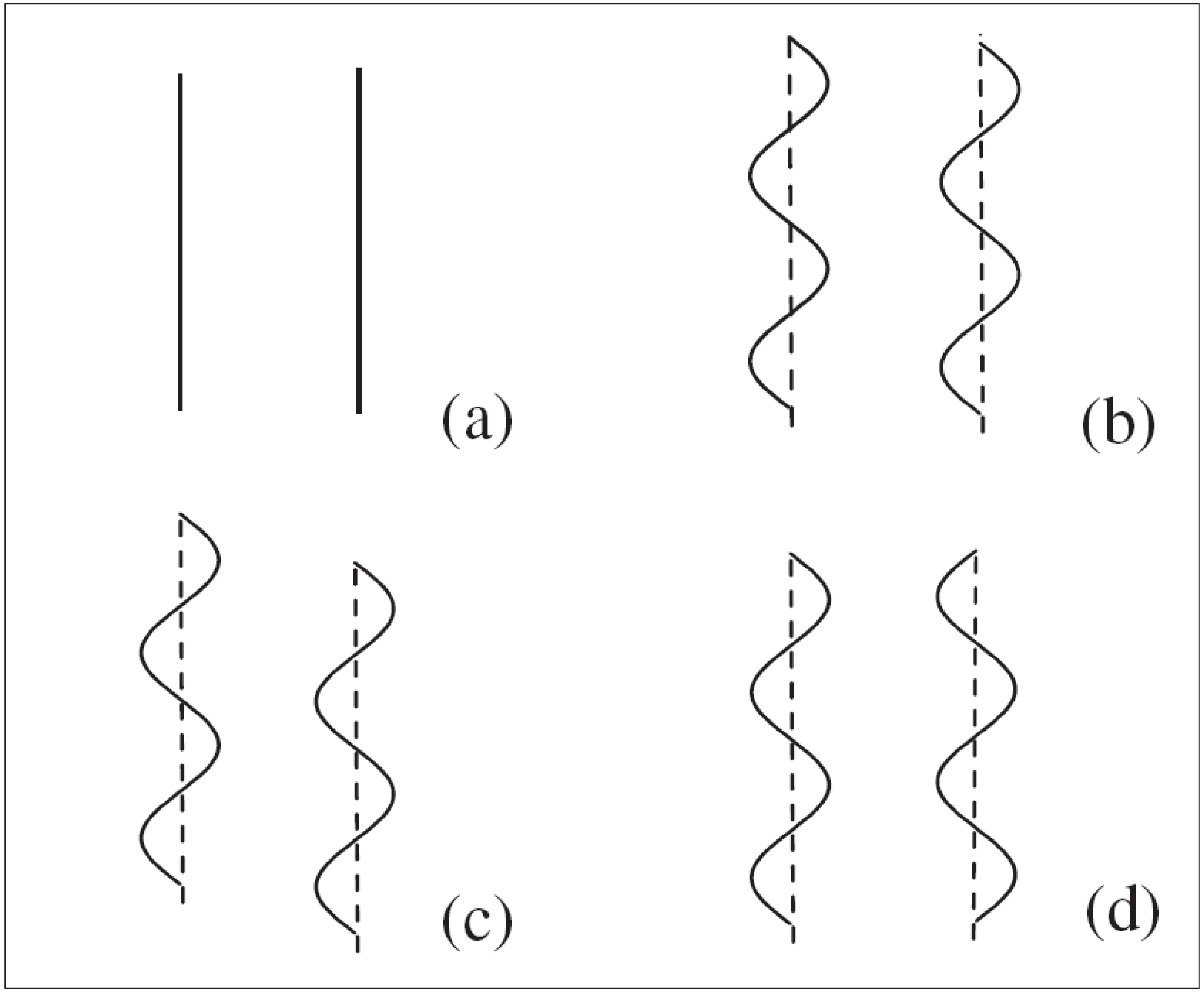
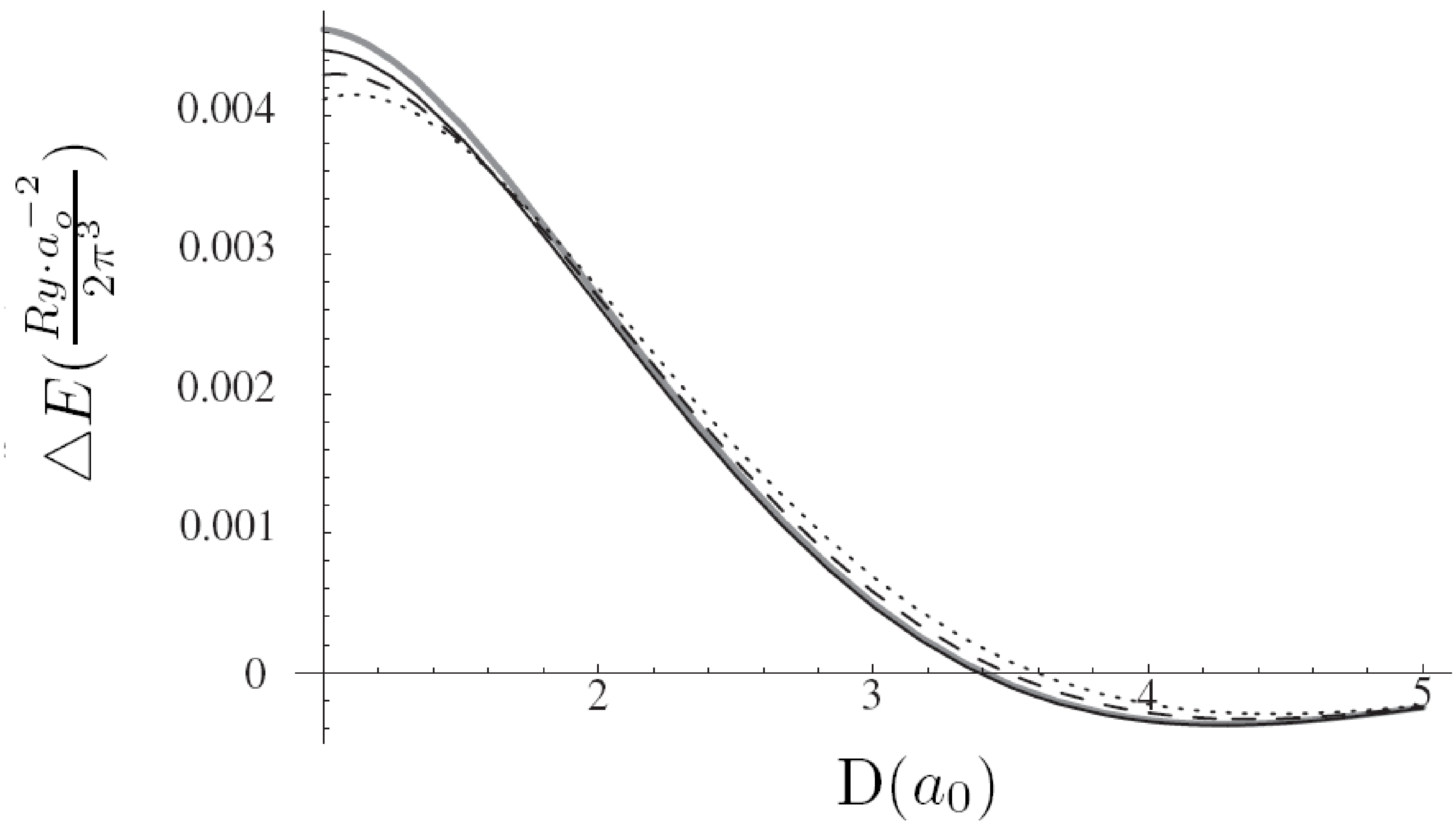
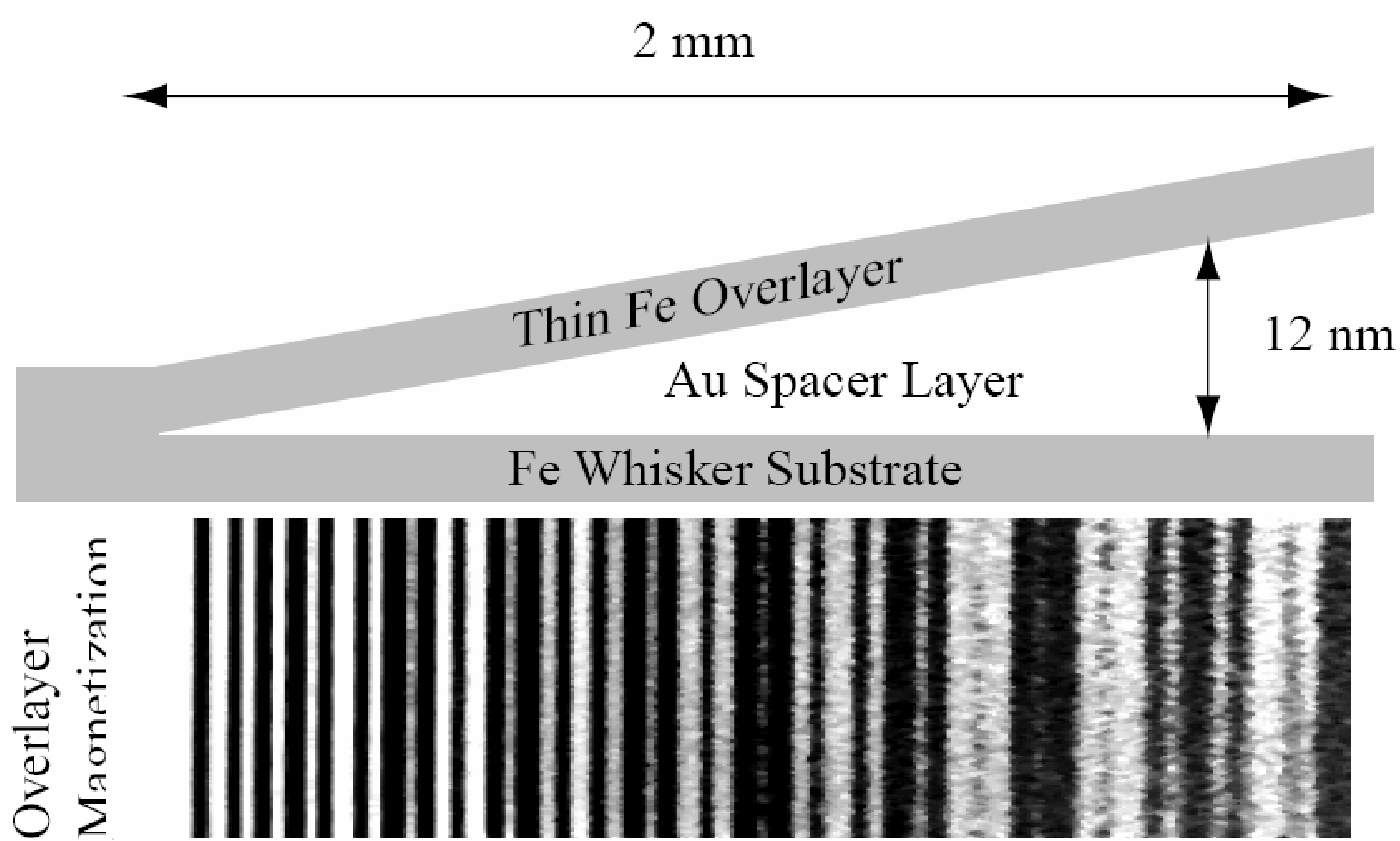


Fig 3: Coupling energy by our perturbative method(solid line) and static average(dashed line) . *Ry* is nature energy unit *Rydberg*, length scale is *Bohr radius*. Parameters: $E_F = 0.2Ry/2\pi^3, V_A = V_B = -0.1Ry/2\pi^3, f = 1/4a_o$.



(a)
(b)
(c)
(d)


0.004
0.003
0.002
0.001
0
2
3
4
5
$\Delta E\left(\frac{Ry \cdot a_o^{-2}}{2\pi^3}\right)$
D(a_0)


2 mm
Thin Fe Overlayer
12 nm
Au Spacer Layer
Fe Whisker Substrate
Overlayer Magnetization

Summary

- We use a new method to handle interface roughness which has physical meaning.
- Interface coupling can be corrected significant.
- Combine lattice structure would be another interesting problem.

References

[1] P. Bruno, Phys. Rev. B **52**, 411 (1995)

[2] J. Kudrnovský, V. Drchal, *et al.*, Phys. Rev. B. **53**, 5125(1996)

[3] M. D. Stiles, J. Magn. Magn. Mater. **200**, 322(1999)