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HIROSHIMA UNIVERSITY

Heavy Electrons

Pressure-induced quantum critical phenomena in $YbNiGe_3$

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Abstract

The electrical resistivity of a single crystal $YbNiGe_3$ has been measured under pressures up to 6.5 GPa and at temperatures down to 0.3K. The resistivity is described as $\rho(T) = \rho_0 + AT^n$ at $T < 20$ K. The coefficient A increases by a factor of 10 with increasing pressure from 3.6 GPa to 6.5 GPa. For $P > 3.6$ GPa, the exponent n decreases below 2, and reaches 1.6 at 6.5 GPa. This value is close to 1.5 expected at the quantum critical point by the spin-fluctuation theory for a three-dimensional antiferromagnet. These findings suggest that the quantum critical point in $YbNiGe_3$ is located at approximately 8 GPa.

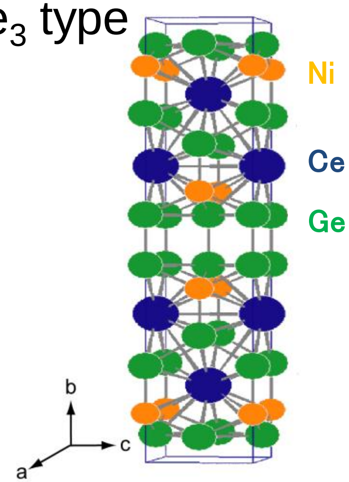
1. Introduction

Pressure-induced superconductivity in a heavy-fermion antiferromagnet $CeNiGe_3$ [1,2]

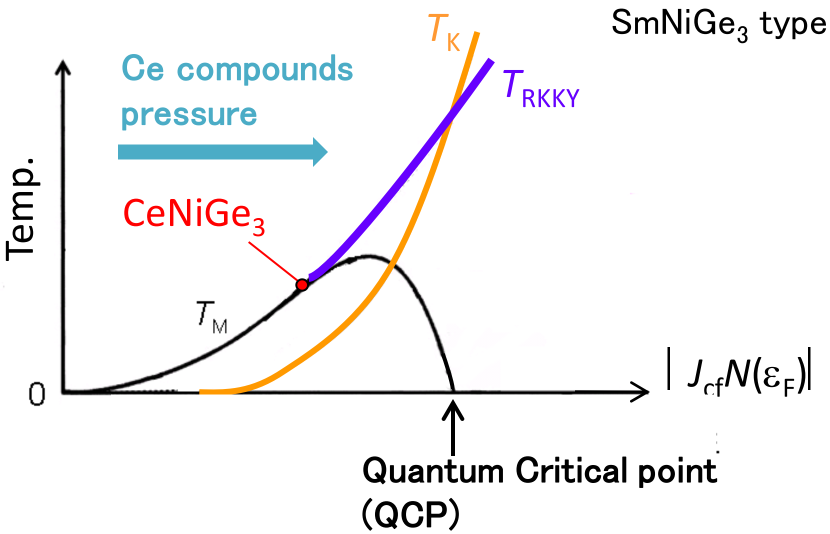
- $CeNiGe_3$
  Orthrohombic $SmNiGe_3$ type

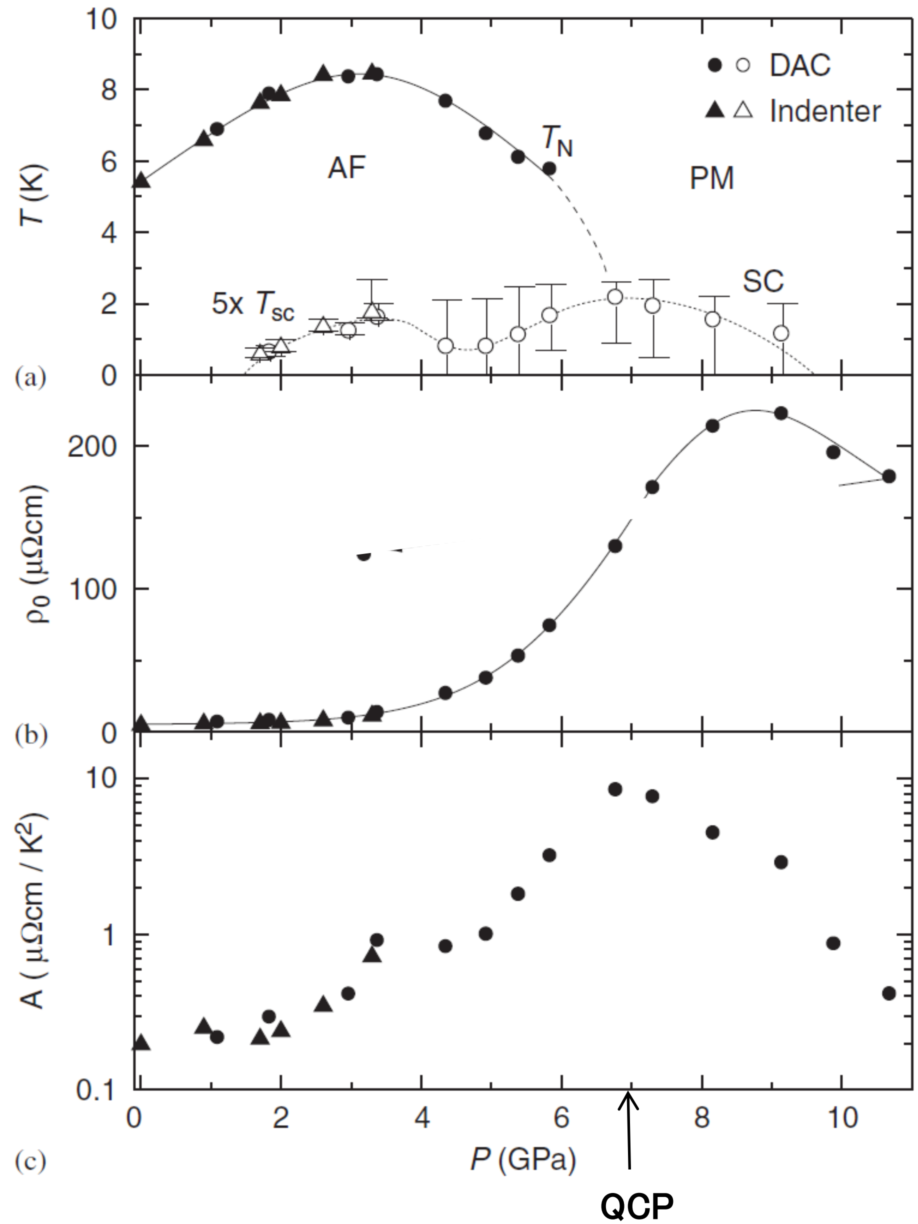
  T_M = 5.5 K @P = 0

  P_c ~ 6-7 GPa [1,2]
  T_{SC} ~ 0.4 K [1,2]



$SmNiGe_3$ type





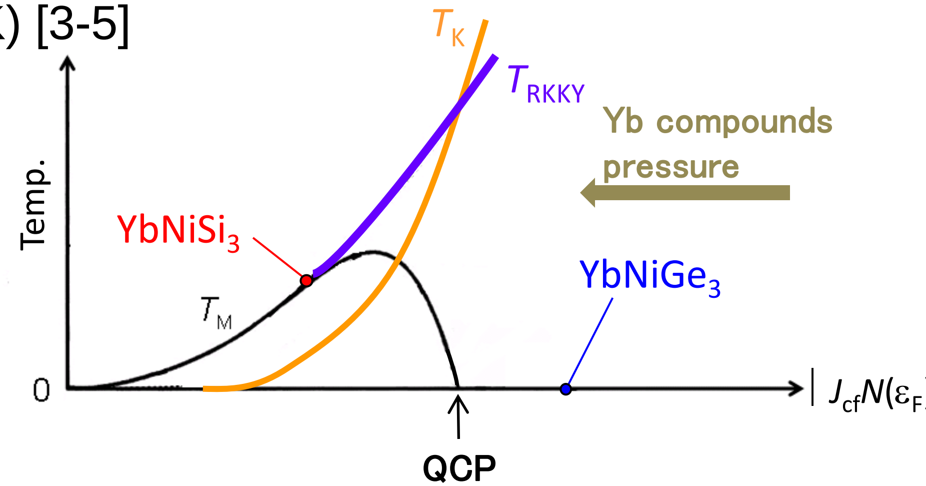
$\rho = \rho_0 + AT^2$

ρ_0 and A have a maximum around QCP.

Search for a pressure-induced superconductivity in Yb compounds ③

- $YbNiSi_3$
  Orthorhombic $SmNiGe_3$ type same as $CeNiGe_3$
  Heavy-fermion antiferromagnet (T_N = 5.1 K) [3-5]

- $YbNiGe_3$
  Orthorhombic $SmNiGe_3$ type
  Non-magnetic ground state at P = 0
  Unit cell volume (V_{UC}) is larger by 12% than that for $YbNiSi_3$ [4,5]



V_{UC}($YbNiGe_3$ @ P =11 GPa) = V_{UC}($YbNiSi_3$ @ P = 0)
(if the bulk modulus is 100 GPa.)

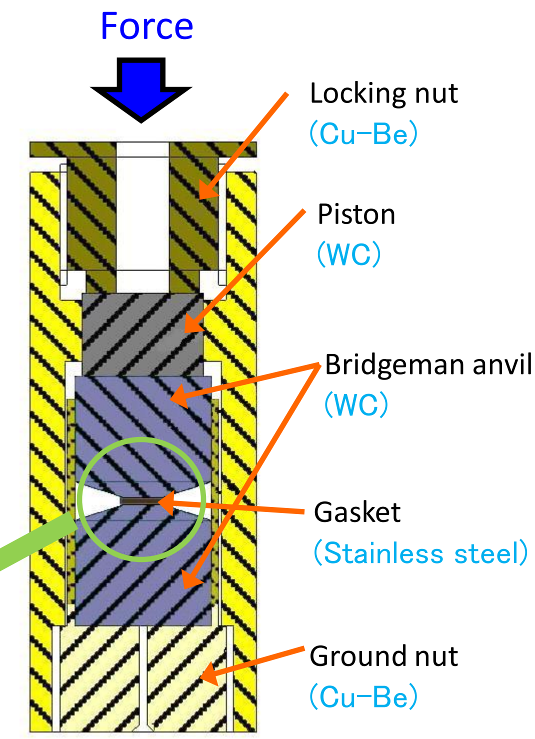
When $YbNiGe_3$ is pressurized, we expect that the ground state changes to a magnetically ordered state through the QCP.

Purpose : Search for a pressure-induced superconductivity in $YbNiGe_3$

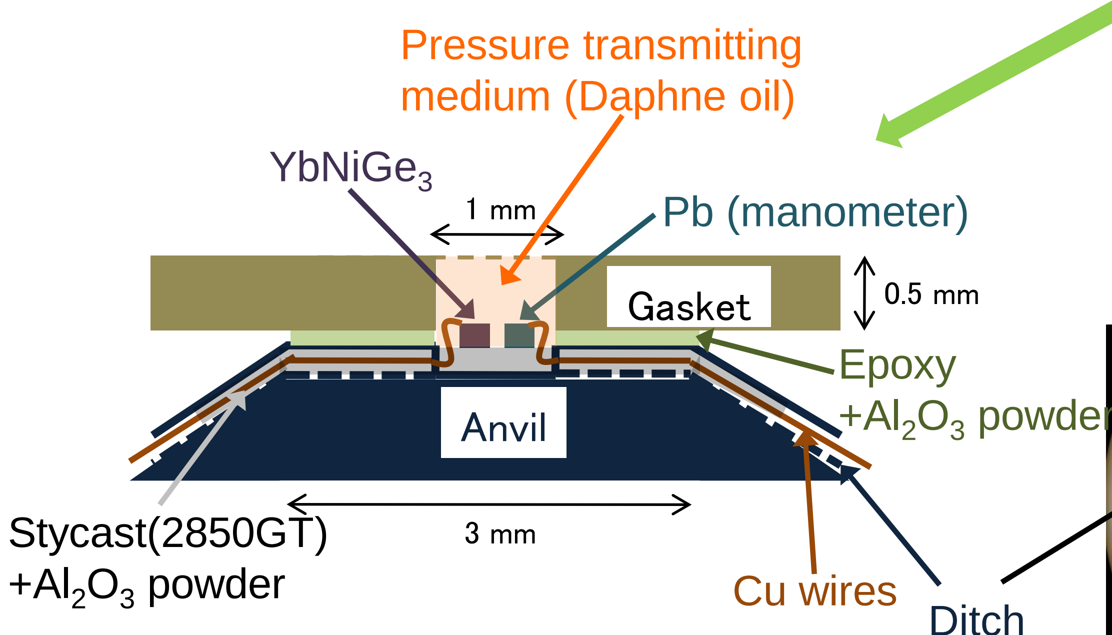
2. Experimental procedure

Electrical resistivity measurement
ac four-terminal method
Clamp type pressure cell
T : 0.3 ~ 300 K (^{3}He cryostat)

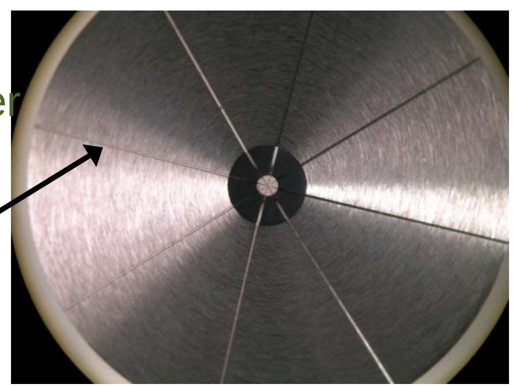
Bridgman anvil cell



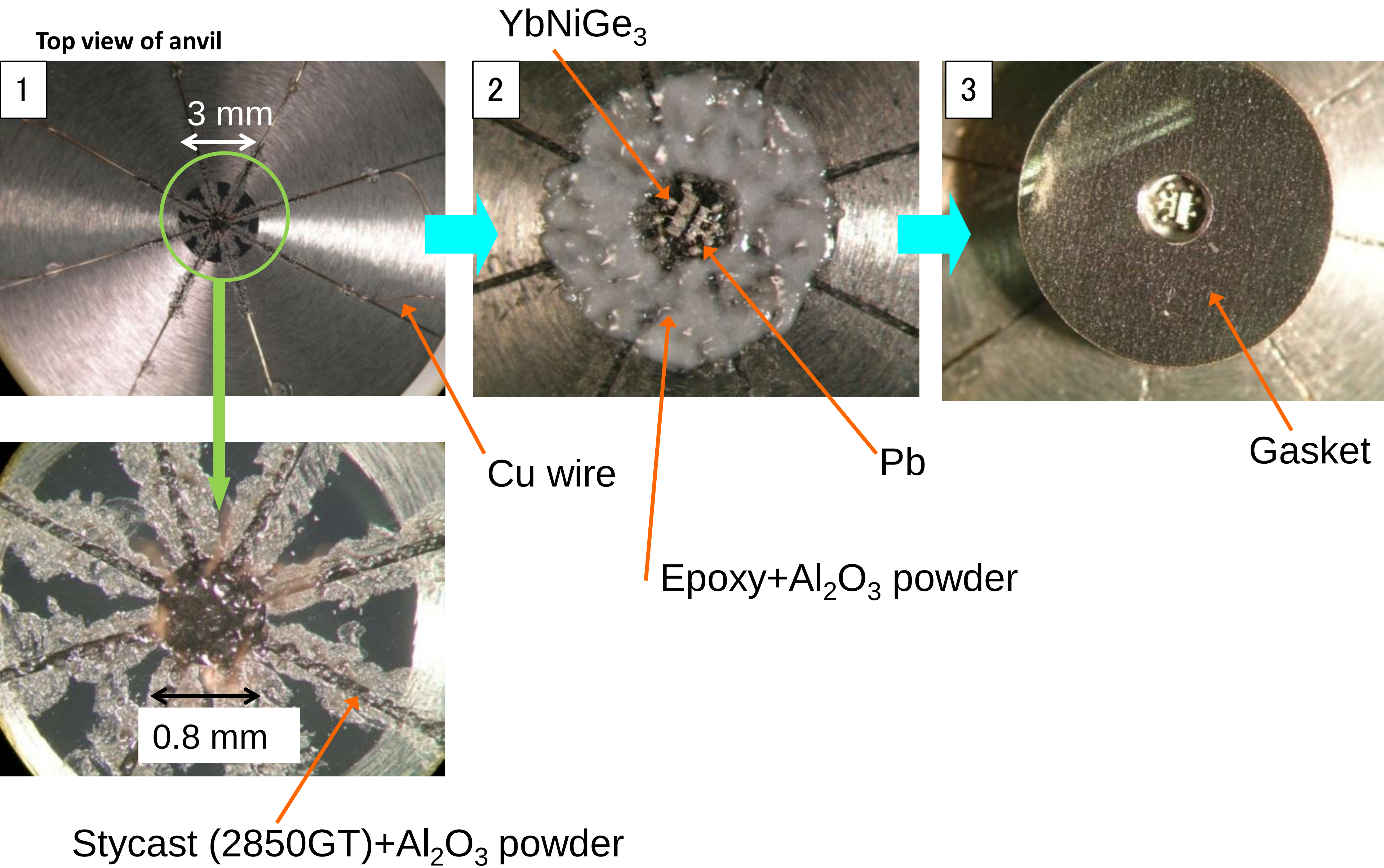
Cross section of the sample space [6]



Top view of anvil

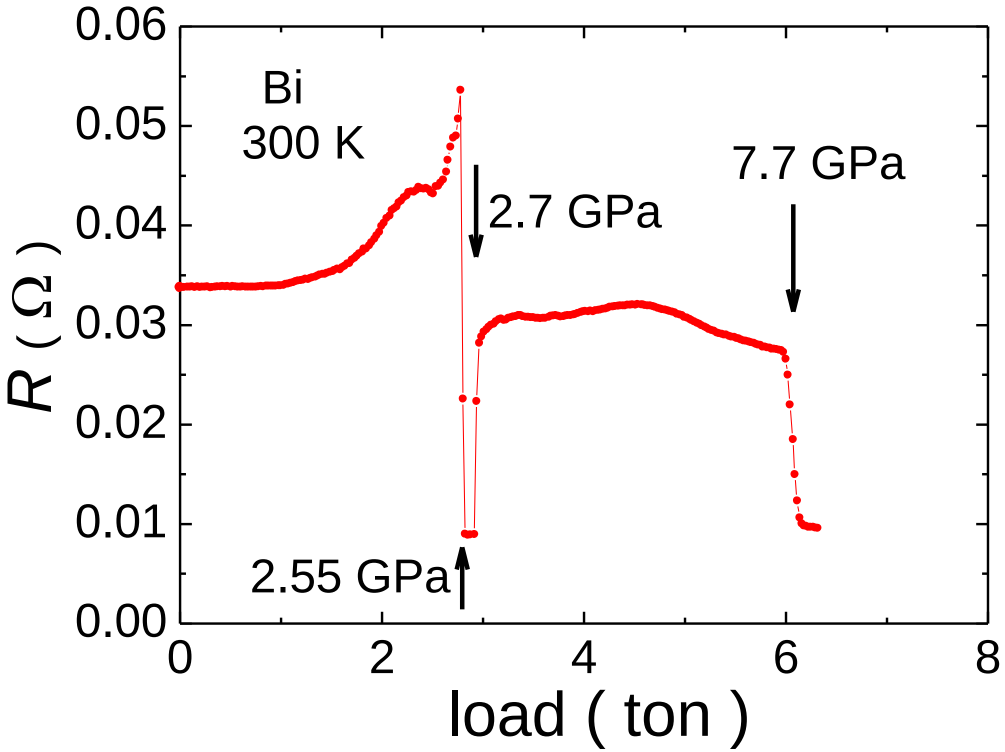


Setting of the samples

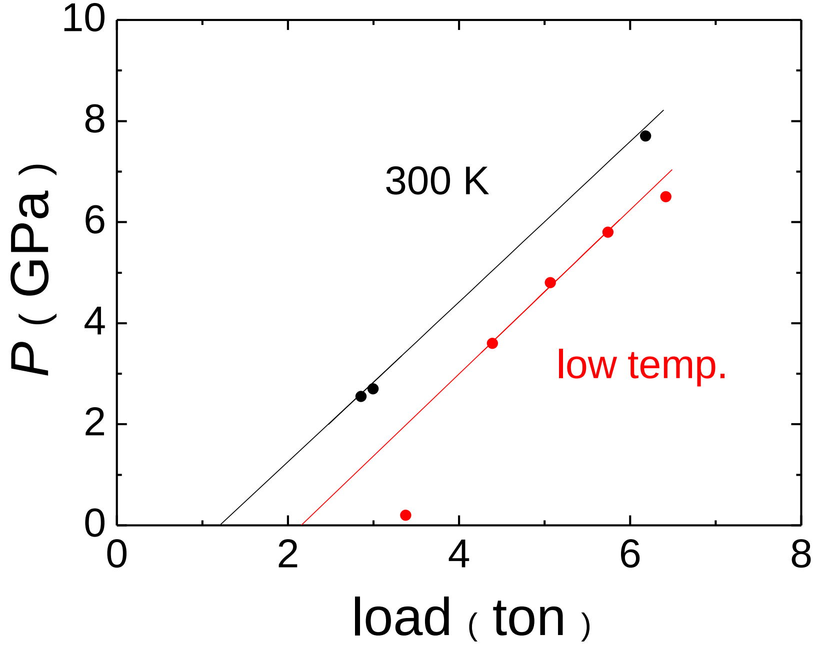


3. Results

Pressure effect on the resistivity of Bi at room temp.

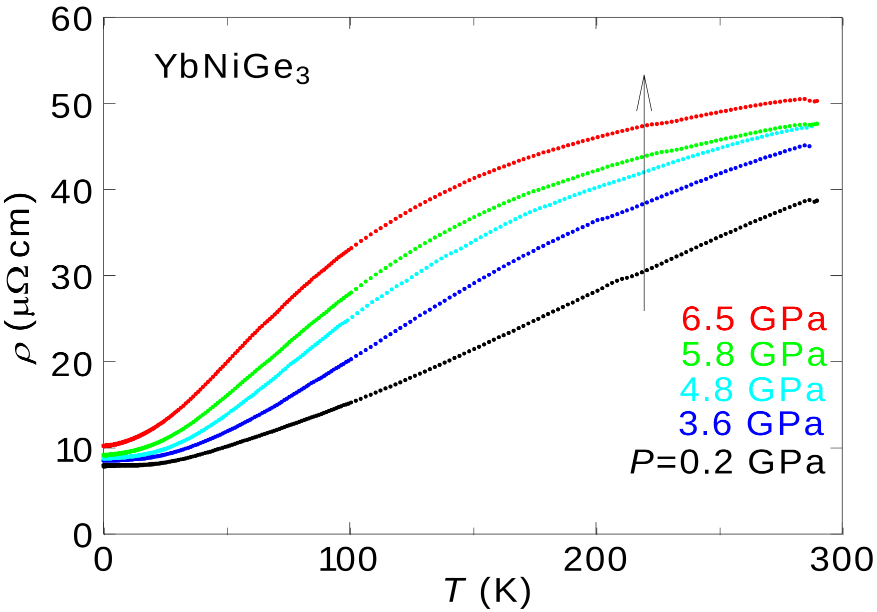


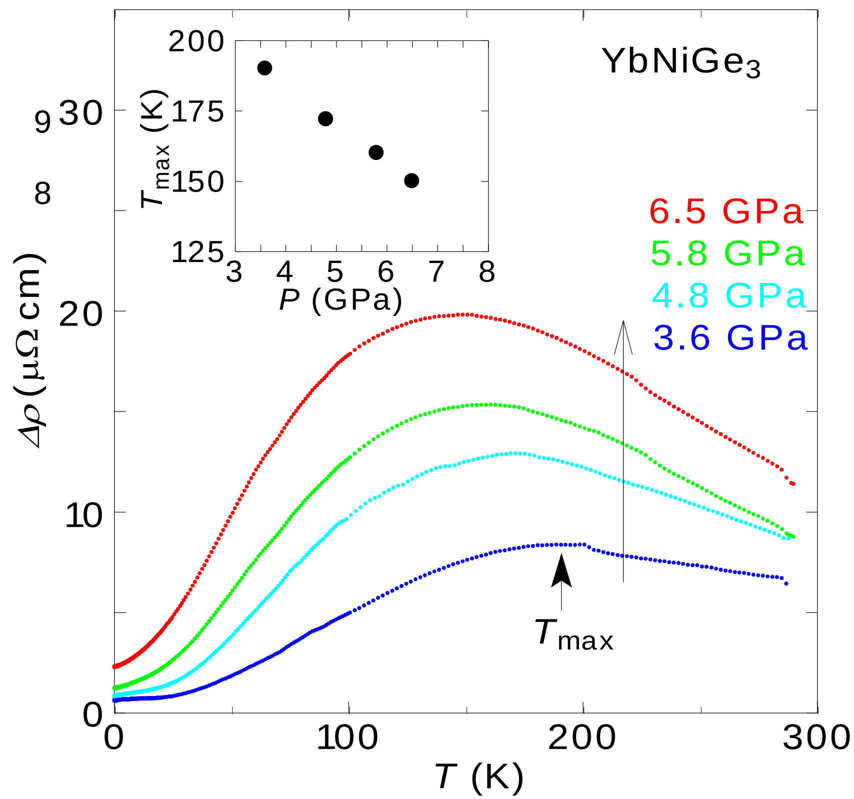
Pressure vs load



Bi : Ⅰ－Ⅱ(2.55 GPa), Ⅱ－Ⅲ(2.7 GPa), Ⅲ－Ⅴ(7.7 GPa)

Electrical resistivity of $YbNiGe_3$ under pressures





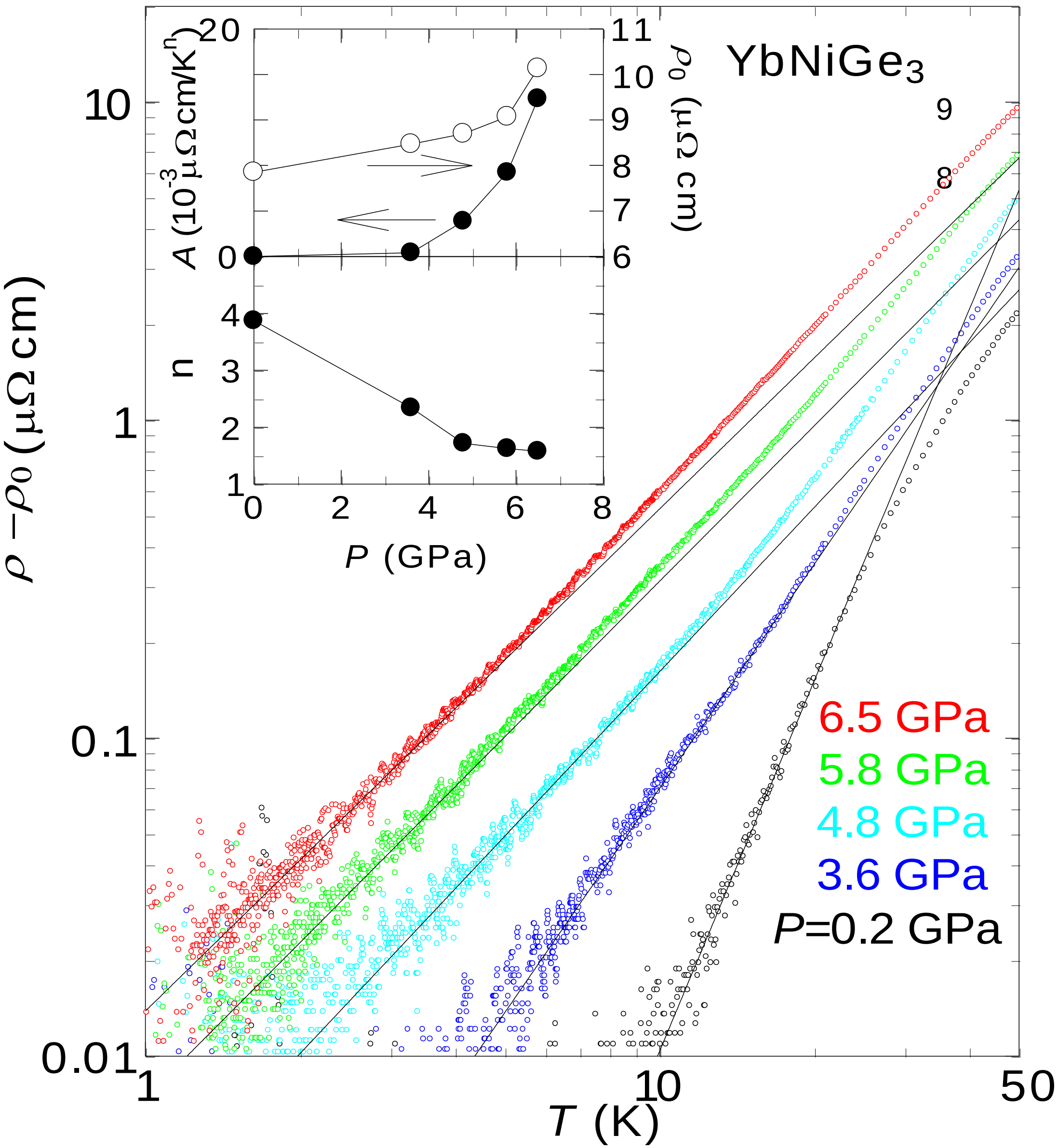
- At P=0, $\rho(T)$ behaves such as a normal metal without the Kondo effect.
- With increasing pressure, the resistivity increases and the Kondo effect manifests itself.

- The magnetic contribution $\Delta\rho$

  $\Delta\rho = \rho(P) - \rho(P = 0.2\ \text{GPa})$
- The maximum at T_{max} is due to the Kondo effect.
- T_{max} decreases linearly with pressure.

$\Rightarrow$ T_K decreases with pressure.

Electrical resistivity of $YbNiGe_3$ at low temperature



- $\rho(T) = \rho_0 + AT^n$ at $T < 20$ K
- ρ_0 and A increase steeply for $P \geq 4$ GPa.

  ⇒approaching QCP

- The exponent n decrease below 2 for $P \geq 4$ GPa.
- The n reaches 1.6 at 6.5 GPa.

⇒spin fluctuation for a three-dimensional antiferromagnet.

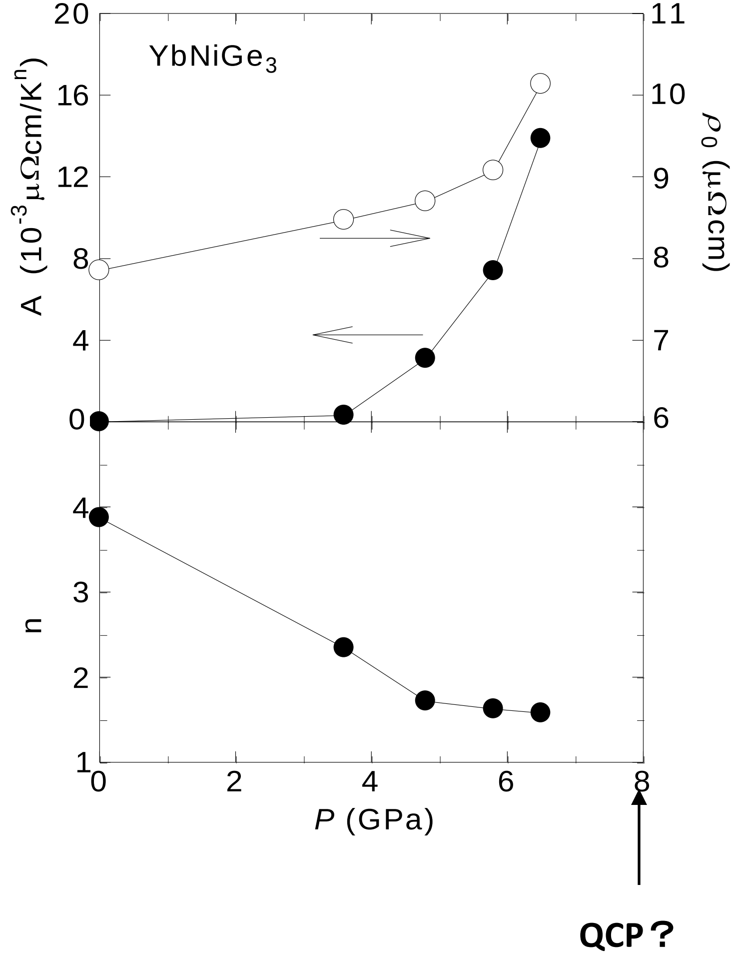
4. Summary

Electrical resistivity of $YbNiGe_3$ under pressures up to 7 GPa.

- T_K increases with pressure.
- The resistivity ρ is described as $\rho(T) = \rho_0 + AT^n$ at T < 20 K.
- For $P \geq 4$ GPa, ρ_0 and A increase steeply, and exponent n decreases below 2.

  ⇒approaching QCP
- At P =6.5 GPa, n reaches 1.6.

  ⇒spin fluctuation for a three-dimensional antiferromagnet.
- QCP is located at about 8 GPa.



References

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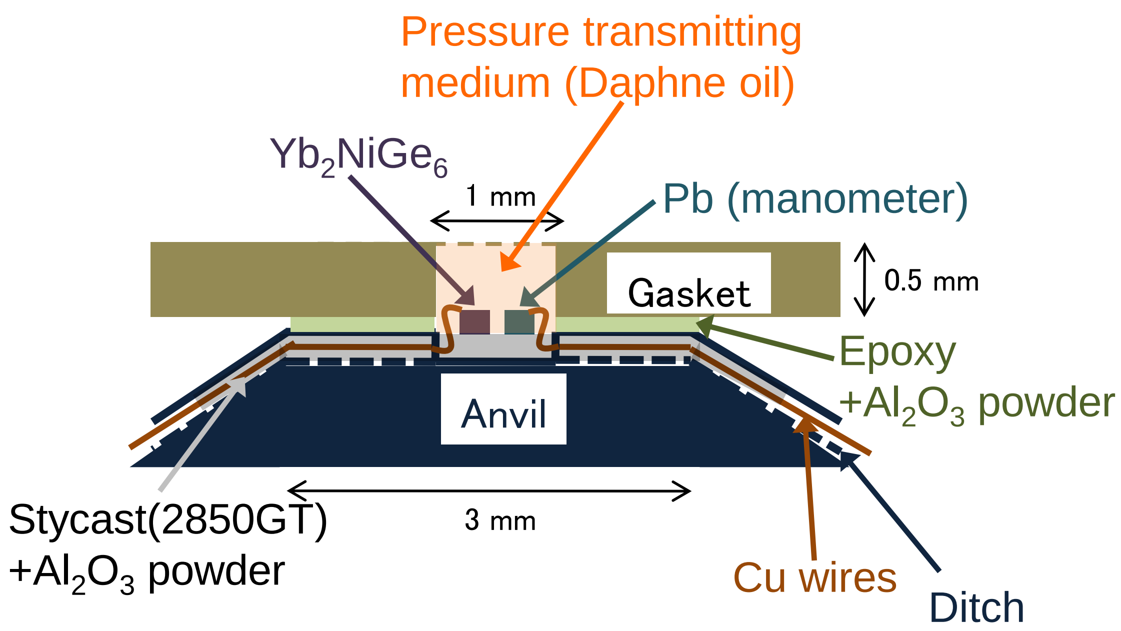
Pressure transmitting
medium (Daphne oil)
Yb_2NiGe_6
1 mm
Pb (manometer)
0.5 mm
Gasket
Epoxy
$+Al_2O_3$ powder
Anvil
Stycast(2850GT)
$+Al_2O_3$ powder
3 mm
Cu wires
Ditch