Temperature Dependent Luminescence of Cr^{3+} Doped $YAl_3(BO_3)_4$ and $GdAl_3(BO_3)_4$

[1,2]Beata Malysa, [2]Andries Meijerink and [1]Thomas Jüstel

[1]Münster University of Applied Sciences, Stegerwaldstrasse 39, D-48565 Steinfurt, Germany

[2]Universiteit Utrecht, Princetonplein 5, 3584 CC Utrecht, The Netherlands

Background

The transition metal ion Cr^{3+} is widely applied in solid state laser gain materials, as a co-dopant for persistent phosphors emitting in the NIR, and as the optical centre in thermographic phosphors for optical sensing [1-2]. Moreover, Cr^{3+} doped luminophores are also considered as NIR emitting materials for in-vivo optical imaging due to the rather high penetration depth of NIR radiation into human tissue [3]. In most of the above mentioned applications the radiation converter is pumped by a blue or NUV emitting (In,Ga)N semiconductor chip. This means that that the radiation converter should not suffer from thermal quenching up to about 450 K, particularly if the converter is directly placed onto the chip [4].

Crystal Structure

The crystal type $RX(BO_3)_4$, where R = Y^{3+} or Gd^{3+} and X = Al^{3+} belongs to a group of double borates which have a huntite $[CaMg_3(CO_3)_4]$ structure with trigonal crystal system in the R32 space group (Fig.1.)[5]. YAB and GAB are excellent hosts for Cr(III)-substitution because they offer only one kind of cation site with octahedral coordination $[AlO_6]^{9-}$.

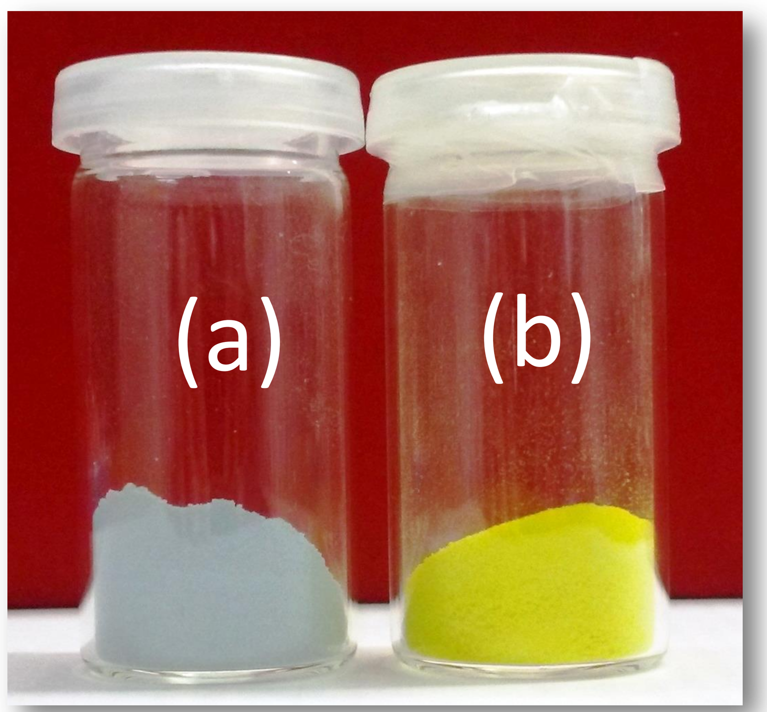

Fig.2. The body color of $YAl_3(BO_3)_4$ (a) and $CaAl_2O_4$ (b) doped with 2% of chromium.

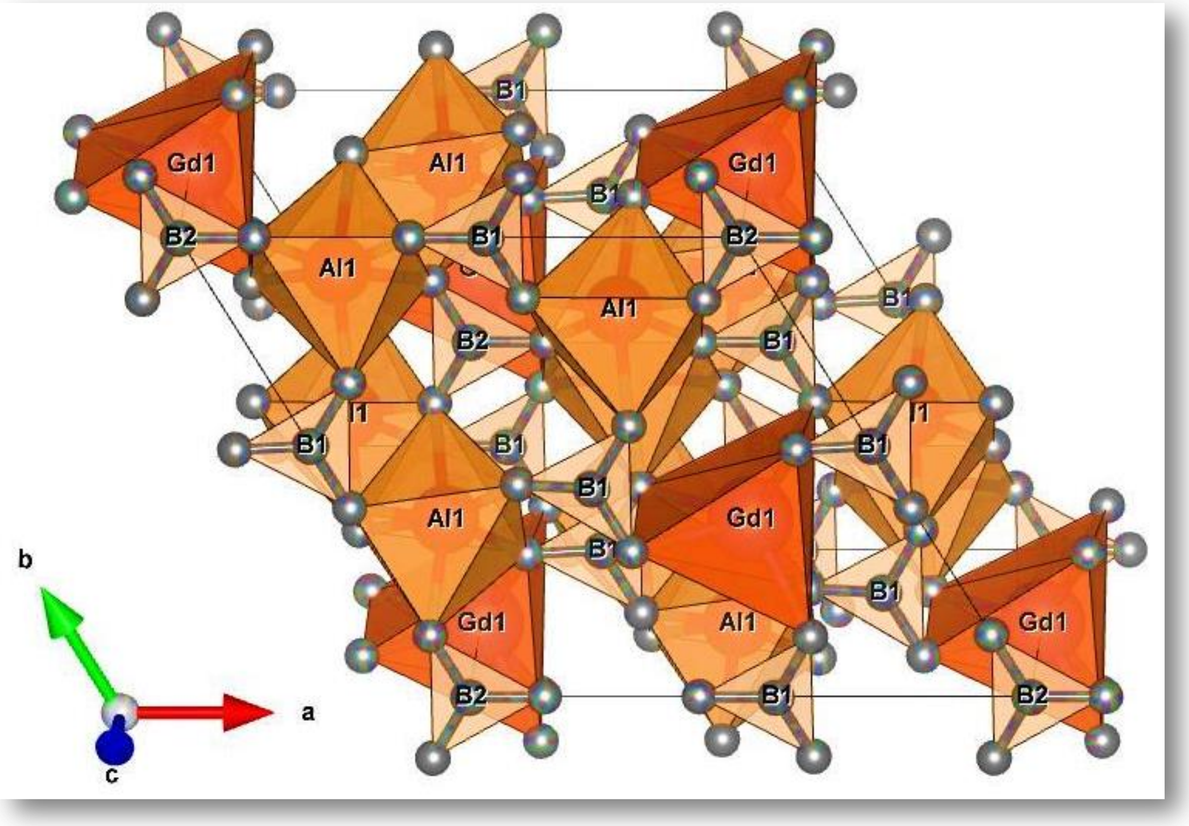

Fig.1. The crystal structure of $GdAl_3(BO_3)_4$.

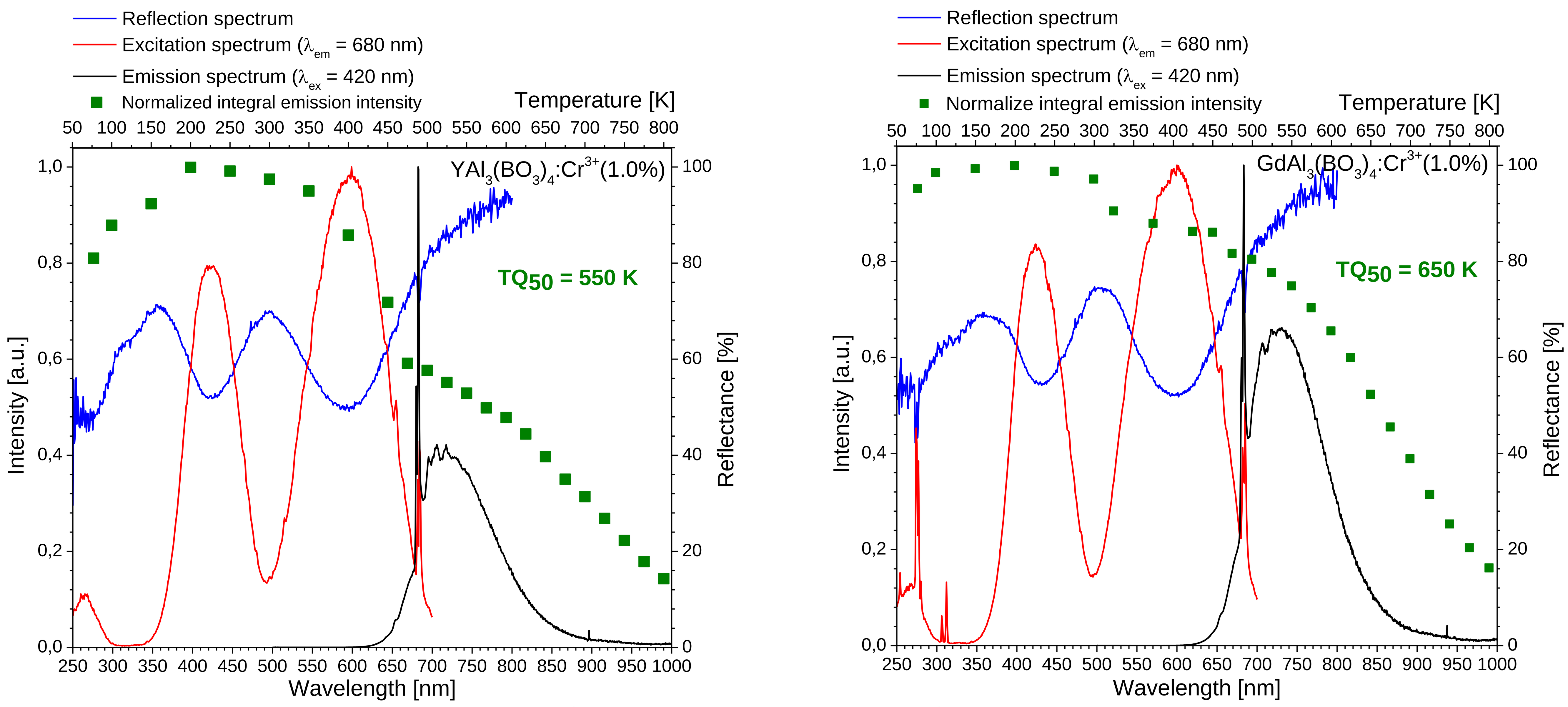

Fig.3. Emission, excitation and reflection spectra of YAB:1%Cr^{3+} (on the left) and GAB:1%Cr^{3+} (on the right) phosphors at room temperature and the their normalized integral emission intensity as a function of temperature in the range 77 – 800 K.

Conclusions

The photoluminescence of Cr^{3+} in $YAl_3(BO_3)_4$ and $GdAl_3(BO_3)_4$ in the temperature range 77 – 800 K was studied. Temperature dependent studies reveal a shift from ^2E to $^4T_2$ emission upon raising the temperature. The quenching temperature of the $^4T_2$ emission is rather high, 550 K for YAB:Cr and 650 K for GAB:Cr. Efficient broad band NIR emission with little thermal quenching of Cr^{3+} is unusual and brands the efficiently NIR emitting YAB:Cr^{3+} and GAB:Cr^{3+} to be promising materials for application in phosphor converted (In,Ga)N LEDs.

Table 1. Crystal field strength, Racah parameters and β-covalency of YAB:Cr and GAB:Cr.

Parameter	YAB:Cr	GAB:Cr
$E(^2E_g)$ [cm^{-1}]	14652	14630
$E(^4T_{2g})$ [cm^{-1}]	16750	16722
$E(^4T_{1g})$ [cm^{-1}]	23640	23474
B [cm^{-1}]	695	677
C [cm^{-1}]	2828	2877
10 Dq [cm^{-1}]	16750	16722
Dq/B	2.4	2.5
$\beta = B/B_0$	0.70	0.68

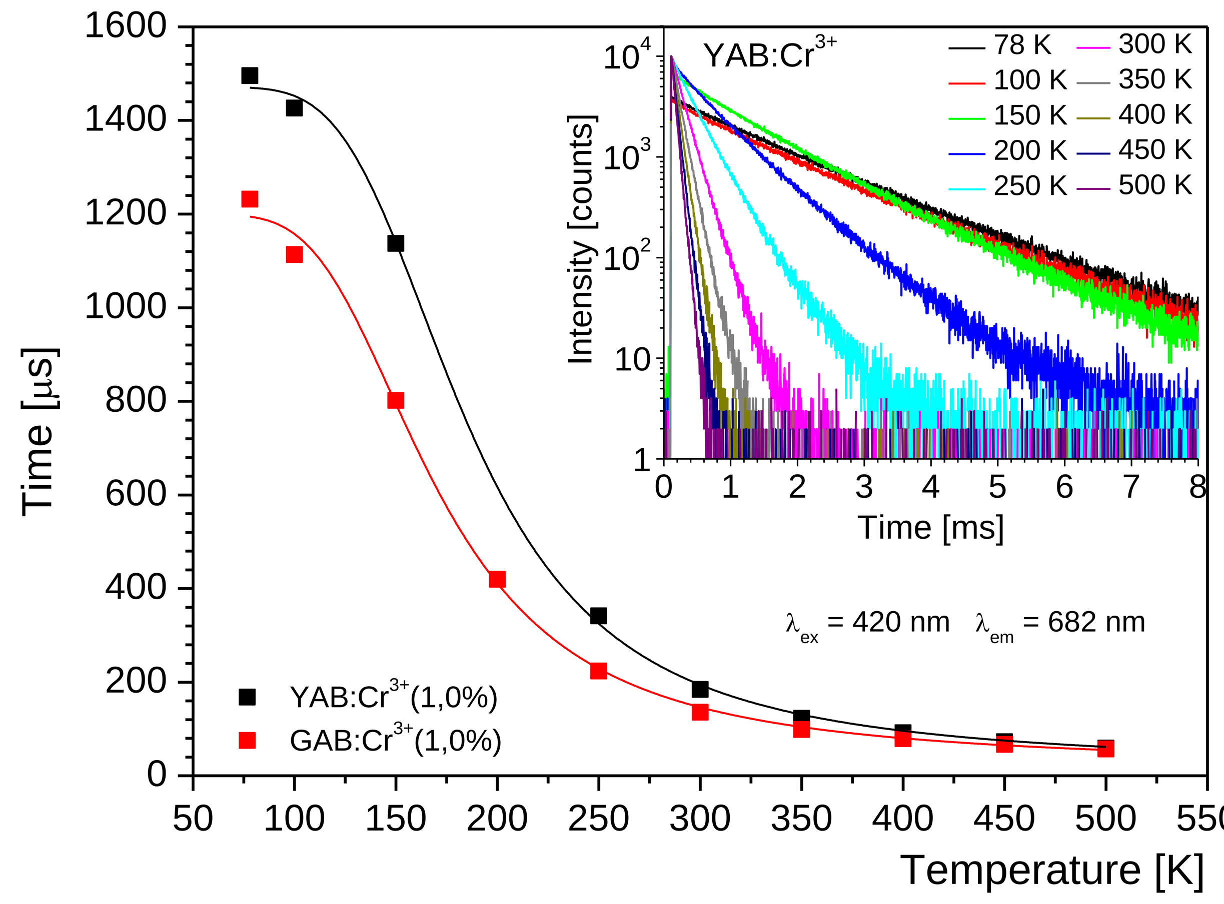

Fig.4. Temperature dependent decay time of the R-line (682 nm) in YAB:Cr^{3+}(1.0%) and GAB:Cr^{3+}(1.0%). The inset displays the luminescence decay curves of YAB:Cr (λ_{ex} = 420 nm.)

References

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Beata Malysa: beata.malysa@fh-muenster.de, Andries Meijerink: a.meijerink@uu.nl, Thomas Jüstel: tj@fh-muenster.de